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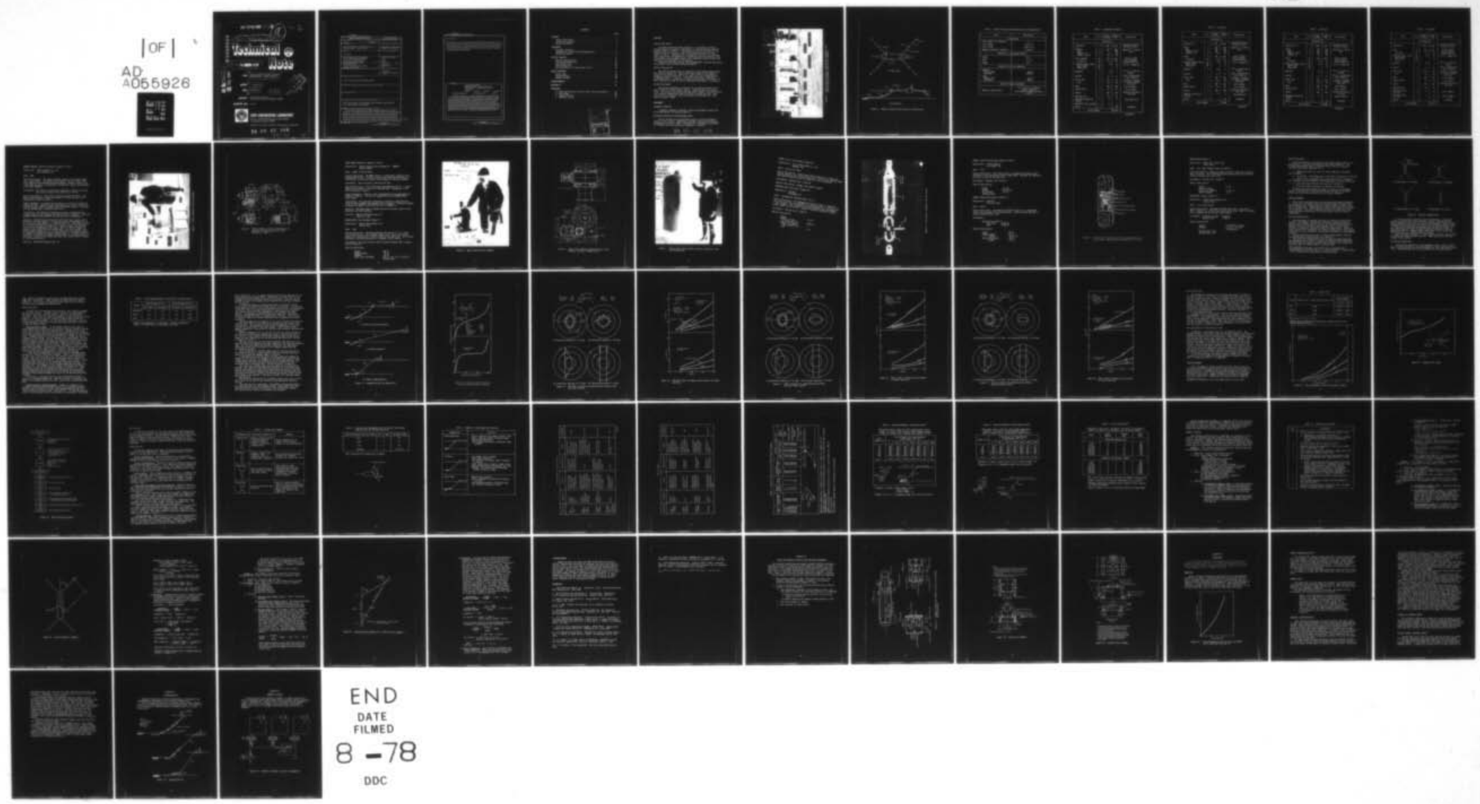

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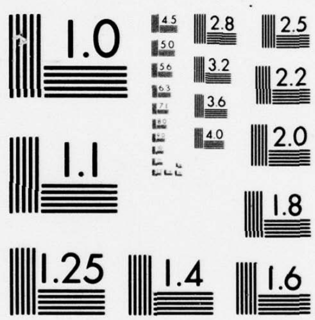

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The modular mooring system is a reusable, multileg mooring system for vessels of opportunity. This document describes modular mooring components, outlines maintenance requirements, and describes system performance. Mooring components were purchased to establish a spread mooring for small ocean construction vessels of the LCM 6 to LCU size. The system components, packaged in four multi-purpose equipment shelters to facilitate shipping and storage, include two hydraulic winches, an anchor windlass, 3,200 ft of 1/2-in. over

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1. Modular mooring system | 2. Containerization | I. 42-027

The modular mooring system is a reusable, multileg mooring system for vessels of opportunity. This document describes modular mooring components, outlines maintenance requirements, and describes system performance. Mooring components were purchased to establish a spread mooring for small ocean construction vessels of the LCM 6 to LCU size. The system components, packaged in four multi-purpose equipment shelters to facilitate shipping and storage, include two hydraulic winches, an anchor windlass, 3,200 ft of 1/2-in. alloy steel chain, four urethane foam mooring buoys, 4,800 ft of braided nylon, and four 200-lb Danforth anchors. Analysis of the system showed that vessel excursion and system stresses in shallow water are especially sensitive to wave excitation. Mooring line forces approaching 10,000 lb are predicted for all vessels in sea state 4 conditions. A suggested mooring design procedure is included.

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CONTENTS

OVERVIEW

General Description

The modular mooring system (Figure 1) is a reusable, multileg mooring system for vessels of opportunity. A typical mooring using the system is shown in Figure 2. The system will restrain vessels of the LCU-1610 size in sea state 4 with 1-knot surface currents in water depths to 200 ft. Components may be assembled with up to four mooring legs, using either all-synthetic or combination chain-buoy-pennant legs. Two hydraulic powered gypsy winches and a combination chain wildcat and gypsy winch are provided for line handling.

This guide describes modular mooring components, outlines maintenance requirements, and describes system performance.

Physical Description

The entire mooring system is contained in four multi-purpose equipment shelters (Figure 1). Gross weight and volume for the complete system are 24,220 lb and 1,664 cu ft. Other critical dimensions and weights are listed in Table 1. A hydraulic power unit, comparable to the NAVSEA Model 1, is required to operate the windlass and winches. A lower capacity unit may be used if diminished performance is acceptable.

Design Environment

The design environmental condition for the mooring system is sea state 4 with a 1.0-knot surface current. Equilibrium forces without waves – due only to the 20-knot wind and 1-knot current – produce mooring line tensions ranging from 1,200 lb (LCM 6) to 4,500 lb (LCU). When wave forces are included, line tensions may reach 10,000 lb for any vessel in these classes.

COMPONENTS

Equipment Inventory

A complete component inventory, along with equipment weight and a brief description, are given in Table 2.

Equipment Description and Performance Data

General descriptive and performance data on selected equipment follow in this section. Appendixes A through D provide more detailed information for several items. Manufacturers' information and manuals are included when the appropriate equipment is supplied.

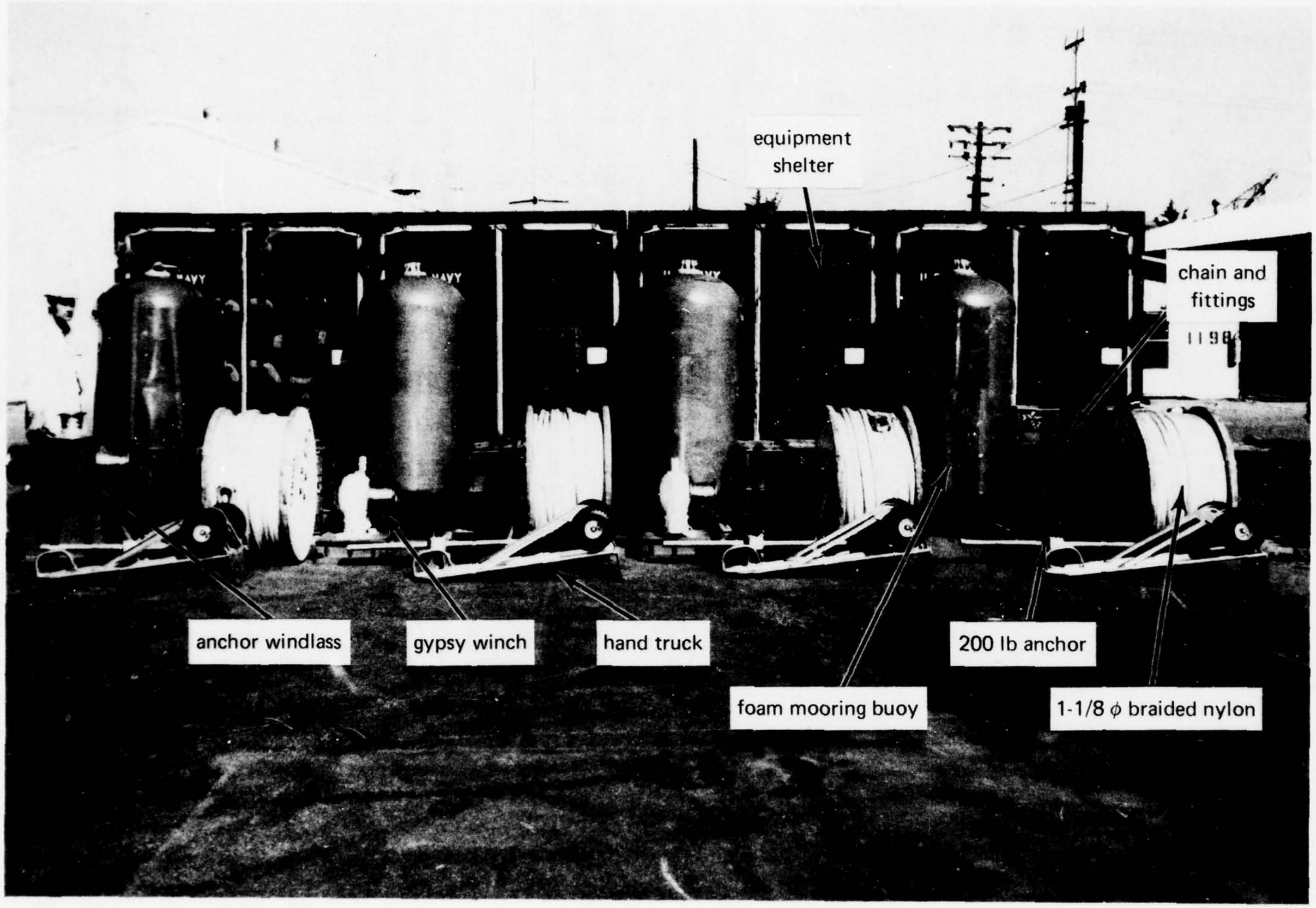

Figure 1. Modular mooring system, identifying components with multi-purpose equipment shelters for shipment.

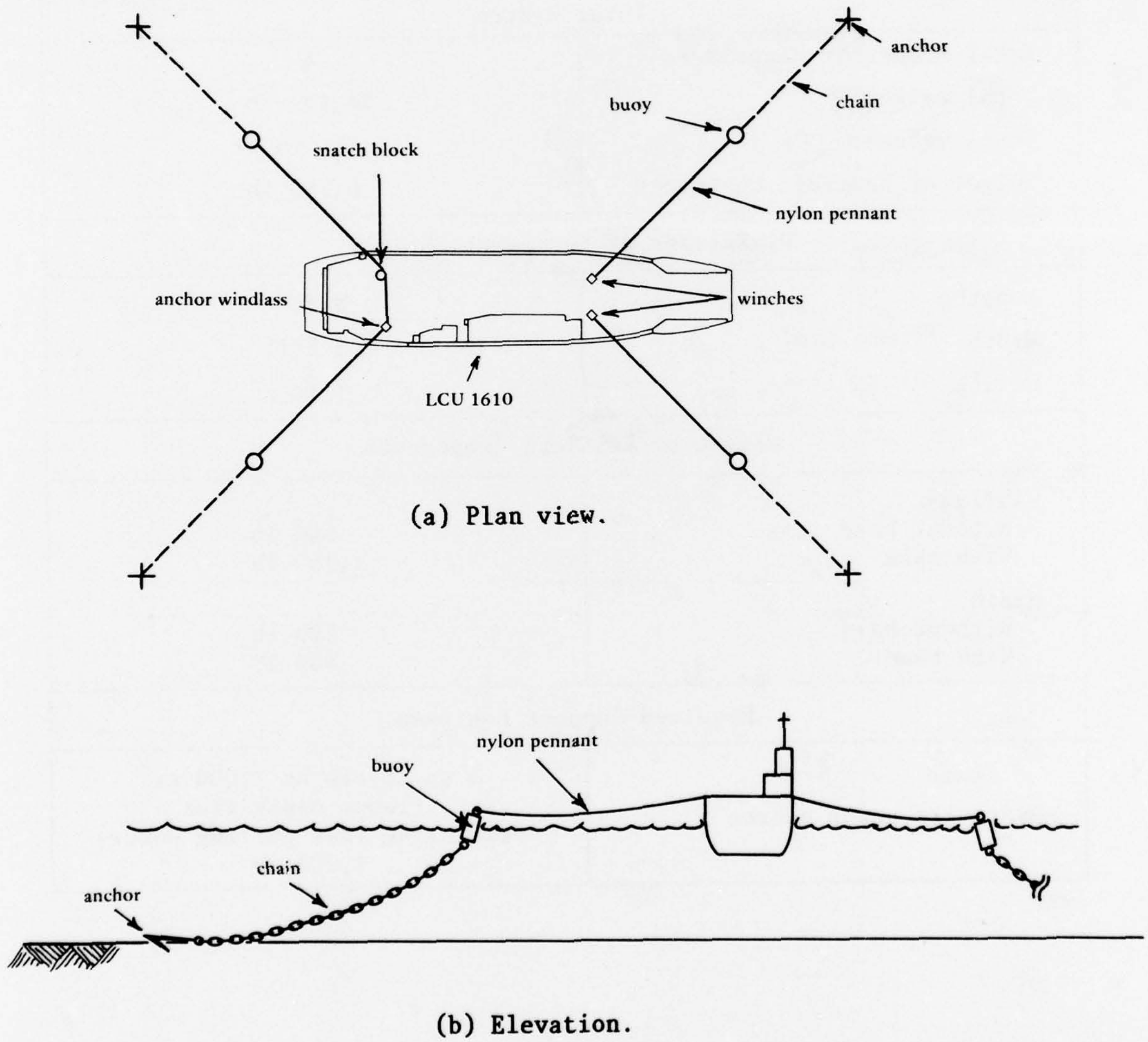

Figure 2. Modular mooring system (typical installation).

Table 1. Modular Mooring System Dimensions and Requirements

Item	Description
Total System	
Total number of containers	4
Total weight	24,220 lb
Total volume	1,664 cu ft
Weight of heaviest container	6,750 lb
Dimensions of Equipment Shelter	
Length	8 ft
Width	6.5 ft
Height	8 ft
Weight of Critical Components	
Windlass	
Without base	680 lb
With base	1,150 lb
Winch	
Without base	190 lb
With base	400 lb
Required Support Equipment	
Hydraulic power source	6 to 18 cfs at 2,000 psi (lower capacities delivering less pulling power) 1,200 lb

Table 2. Equipment Inventory

Item	No.	Weight, lb (ea)	Weight, lb	Description
Container I				
Container I	1	1,950	1,950	Equipment Shelter, 8 x 6.5 x 8 ft
Windlass	1	680	680	Hydraulic, 2,500 lb pull
base	1		395	
adaptor, Al	2	15	30	
adaptor, steel	2	40	80	
Chain lengths	10	240	2,400	1/2-in. alloy, 80-ft lengths
container	10	6.5	65	Polyethylene box
Coupling links, chain	15	1.4	21	1/2-in., Hammerlok
spare studs	25		5	
spare pins	25		5	
Shackles	9	0.2	2	3/4-in., Screw pin, anchor
Swivels	1	15	15	7/8-in. Ballbearing, 5-ton capacity
Nylon rope	2	216	432	1-1/8-in., Braided
reel	1	60	60	2 x 600-ft lengths per reel
Buoy	1	290	290	Cast urethane
Snatch block	2	27	54	6-in. sheave
Anchor	1	200	200	Danforth Hi-Tensile for sand
Hauling line	1	20	20	
Hydraulic direction control	1	5	5	Three-position
Hydraulic flow control	1	5	5	
Dolly	1		40	Aluminum
Total Weight			6,750	

continued

Table 2. Continued

Item	No.	Weight, lb (ea)	Weight, lb	Description
Container II				
Container II	1	1,950	1,950	Equipment Shelter, 8 x 6.5 x 8 ft
Winch	1	190	190	Hydraulic, 5,000-lb pull
base	1	130	130	
adaptor, steel	1	80	80	
adaptor, Al	1	40	40	
Chain	10	240	2,400	1/2-in. alloy, 80-ft lengths
container	10	6.5	65	Polyethylene box
Coupling links, chain	15	1.4	21	1/2-in., Hammerlok
spare studs	25		5	
spare pins	25		5	
Shackles	7	0.2	2	3/4-in., Screw pin, anchor
Swivels	1	15	15	7/8-in. Ballbearing, 5-ton capacity
Nylon rope	2	216	432	1-1/8-in., Braided, 2 x 600-ft lengths per reel
reel	1	60	60	
Buoy	1	290	290	Cast urethane
Snatch block	2	27	54	6-in. sheave
Anchor	1	200	200	Danforth Hi-Tensile for sand
Hydraulic direction control	1	5	5	Three-position
Dolly	1		40	Aluminum
Total Weight			5,980	

continued

Table 2. Continued

Item	No.	Weight, lb (ea)	Weight, lb	Description
Container III				
Container III	1	1,950	1,950	Equipment Shelter, 8 x 6.5 x 8 ft
Winch	1	190	190	Hydraulic, 5,000-lb pull
base	1	130	130	
adaptor, steel	1	80	80	
adaptor, Al	1	40	40	
Chain	10	240	2,400	1/2-in. alloy, 80-ft lengths
container	10	6.5	65	Polyethylene box
Coupling links, chain	15	1.4	21	1/2-in., Hammerlok
spare studs	25		5	
spare pins	25		5	
Shackles	7	0.2	2	3/4-in., Screw pin, anchor
Swivels	1	15	15	7/8-in., Ballbearing, 5-ton capacity
Nylon rope	2	216	432	1-1/8-in., Braided, 2 x 600-ft lengths per reel
reel	1	60	60	
Buoy	1	290	290	Cast urethane
Snatch block	2	27	54	6-in. sheave
Anchor	1	200	200	Danforth Hi-Tensile for sand
Hydraulic direction control	1	5	5	Three-position
Dolly	1		40	Aluminum
Total Weight			5,980	

continued

Table 2. Continued

Item	No.	Weight, lb (ea)	Weight, lb	Description
Container IV				
Container IV	1	1,950	1,950	Equipment Shelter, 8 x 6.5 x 8 ft
Chain	10	240	2,400	1/2-in. alloy, 80-ft lengths
container	10	6.5	65	Polyethylene box
Coupling links, chain	15	1.4	21	1/2-in., Hammerlok
spare studs	25		5	
spare pins	25		5	
Shackles	7	0.2	2	3/4-in., Screw pin, anchor
Swivels	3	15	45	7/8-in., Ballbearing, 5-ton capacity
Nylon rope	2	216	432	1-1/8-in., Braided, 2 x 600-ft lengths
reel	1	60	60	per reel
Buoy	1	290	290	Cast urethane
Snatch block	2	27	54	6-in. sheave
Anchor	1	200	200	Danforth Hi-Tensile for sand
Hauling line	1	20	20	
Hydraulic hose, 3/4 inch	10	8	80	30-ft lengths
Hydraulic hose, 1/2 inch	7	6	40	30-ft lengths
Dolly	1		40	Aluminum
Total Weight			5,510	

ANCHOR WINDLASS, Hydraulic-operated (Figures 3 and 4)

Manufacturer: Ideal Windlass Co., Inc.
East Greenwich, R.I.

Model: HDR

General Description: The anchor windlass consists of two gypsy drums and a chain wildcat. The wildcat was forged to fit the 1/2-in. alloy chain supplied with the modular mooring system. Forward, reverse, and locked drum operation is provided by a directional control valve mounted on the base assembly.

Performance: The wildcat and horizontal gypsy pull 2,500 lb at 25 fpm. The vertical capstan pulls 2,100 lb at 30 fpm.

Physical Description: The windlass weighs approximately 680 lb. The bronze gypsy drums and wildcat are mounted on a cast-iron gear case. Dimensions are shown in Figure 4.

Support Equipment: A suitable lifting device is required to place the windlass on deck. Hydraulic power requirements are 7 gpm at 2,000 psi. A hydraulic flow control provided with the windlass allows it to be used with the NAVSEA Model 1 hydraulic power unit.

Installation: The windlass is mounted on vessels of opportunity by using the special base assembly and adaptors shown in Figure 3. Detailed assembly drawings and suggested location plans are in Appendix A.

Operation: The windlass is operated by the directional control valve mounted on the base assembly. To drop the anchor, the handbrake is set by turning the brake wheel in a clockwise direction. The anchor can now be let go by releasing the brake (or if hung on a davit, by releasing the brake and tripping the davit hook). Scope of chain and speed of paying out are controlled by the brake wheel. To ride at anchor, the brake or chain stopper is set. To haul the anchor, the wildcat clutch is engaged by turning the wildcat release wheel in a clockwise direction. The brake is released by turning the brake wheel in a counterclockwise direction. To haul in the anchor and chain, the control valve is turned to the forward position.

Lubricant: SAE 90 multipurpose gear oil.

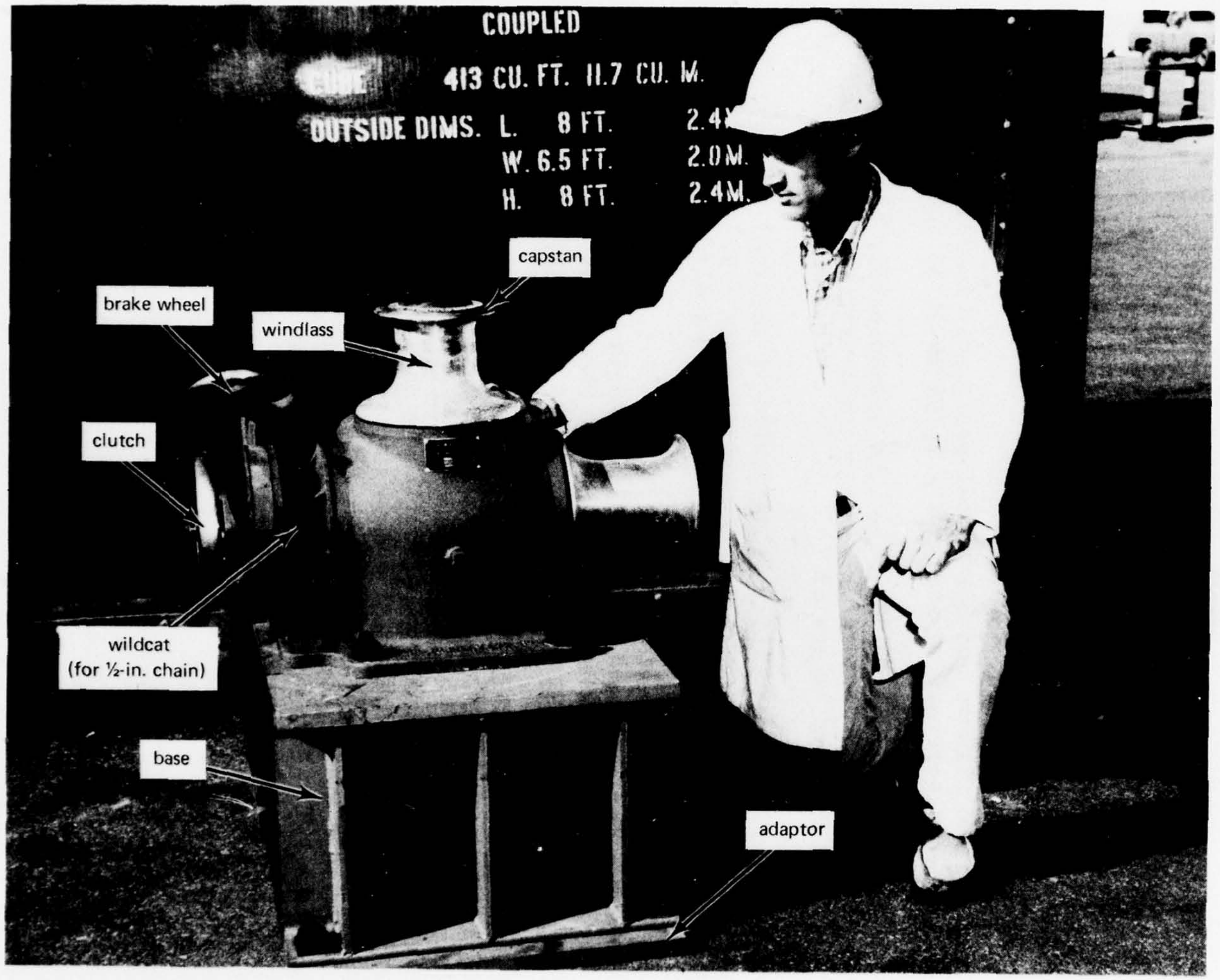

Figure 3. Anchor windlass and base assembly.

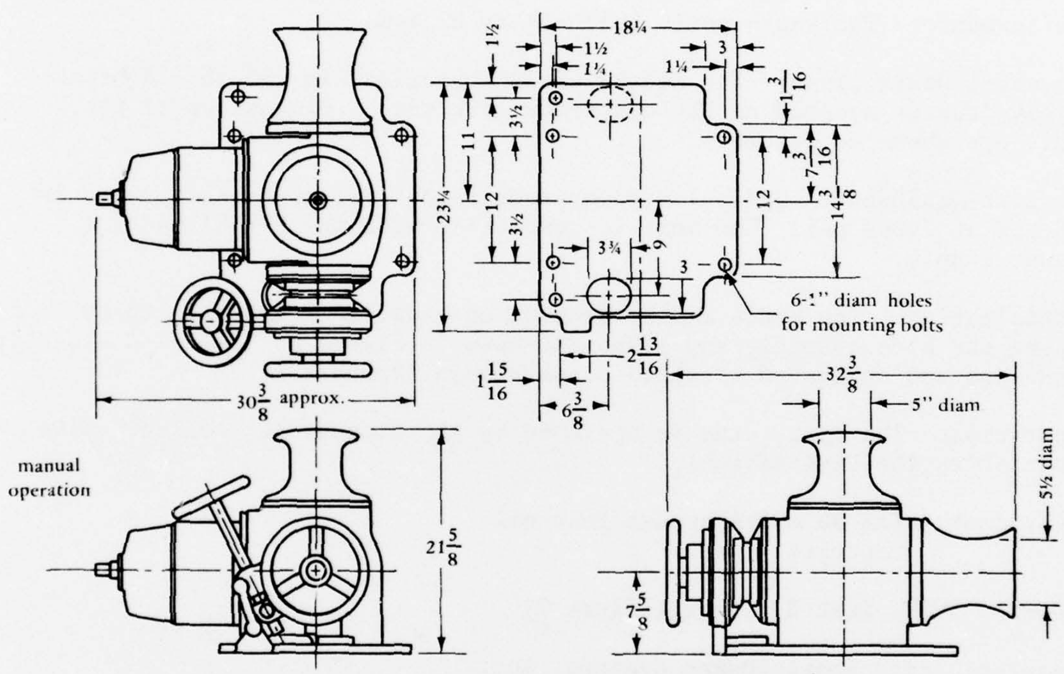

Figure 4. Anchor windlass, physical characteristics (windlass drawing, courtesy of Ideal Windlass Co., Ref 1).

GYPSY WINCH, Hydraulic (Figures 5 and 6)

Manufacturer: Marine Construction and Design Co. (MARCO)
Seattle, Wash.

Model: W2020, Corkline Winch

General Description: The MARCO winch is a heavy-duty, synthetic-line-handling gypsy winch. Forward, reverse, and locked-drum operation is provided by a directional control valve mounted on the base assembly.

Performance: The winch pulls 5,470 lb at 87 fpm.

Physical Description: The winch weighs approximately 190 lb. A bronze gypsy drum is mounted on the cast-iron gear case. Dimensions of the unit are shown in Figure 6.

Support Equipment: Hydraulic power requirement for full performance is 18 gpm at 2,000 psi. The unit is compatible with the NAVSEA Model 1 power supply.

Installation: The winch may be mounted on vessels of opportunity by using the base assembly and adaptors shown in Figure 5. Detailed assembly drawings and suggested location plans are in Appendix A.

Operation: The gypsy drum is operated by the directional control valve mounted on the base assembly.

Lubricant: SAE 90 multipurpose gear oil
Capacity, 1 gal.

MOORING BUOY, Cast Urethane (Figure 7)

Manufacturer: Samson Ocean Systems, Inc.
Boston, Mass.

Model: None

General Description: The Samson mooring buoy (Figure 7) is a closed cell foam buoy with a cast-urethane rubber cover. Steel rod tension members are incorporated to sustain high pull through leads. All external steelwork is hot-dip galvanized to a minimum 2.5-mil coating.

Performance: The buoy provides 1,500 lb reserve buoyancy and a working load of 40,000 lb.

Physical Description:

Weight	290 lb
Length overall	82 in.
Diameter	32 in.
Outer cover thickness	3/8 in. to 2 in. in critical stress areas.

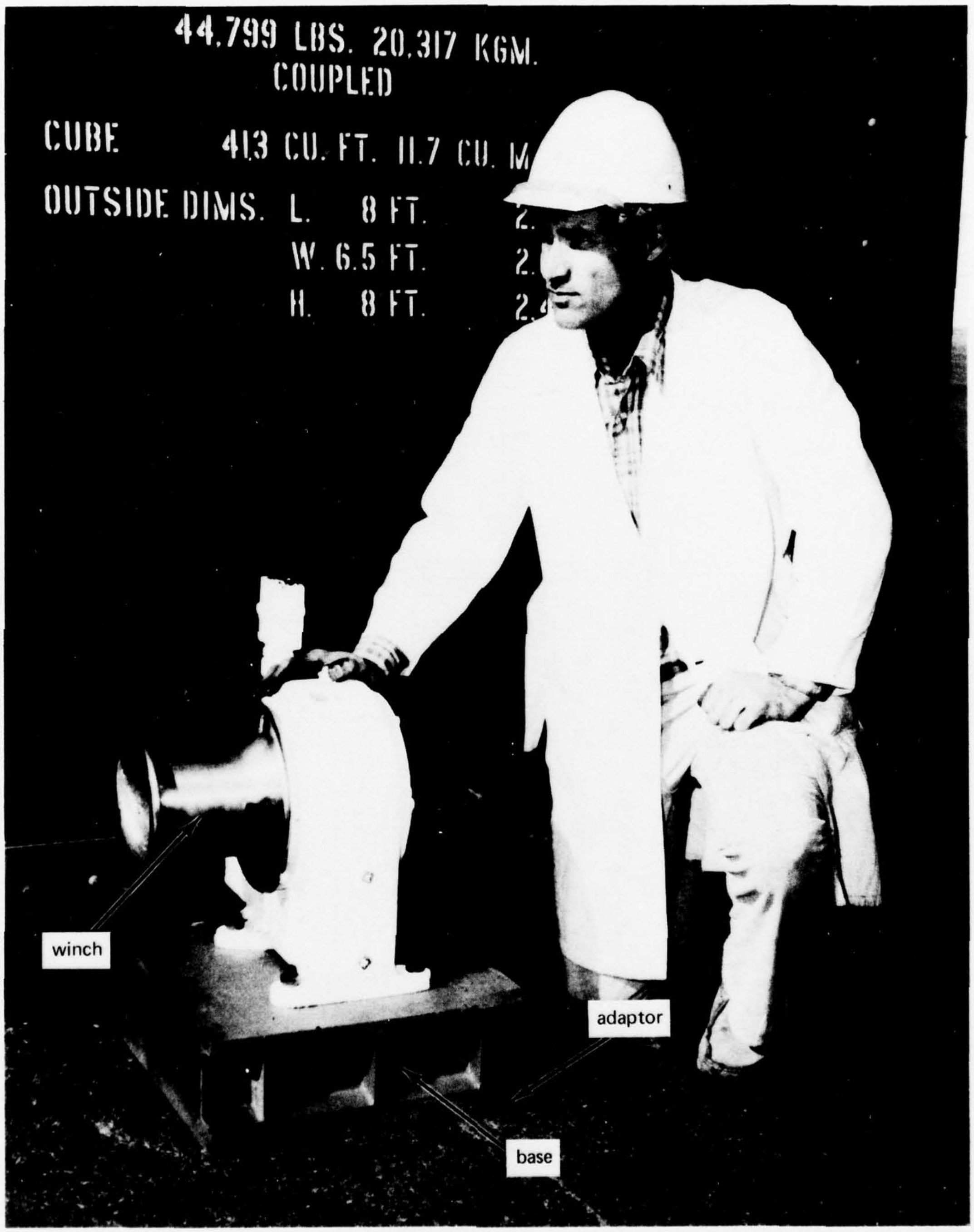

Figure 5. Gypsy winch and base assembly.

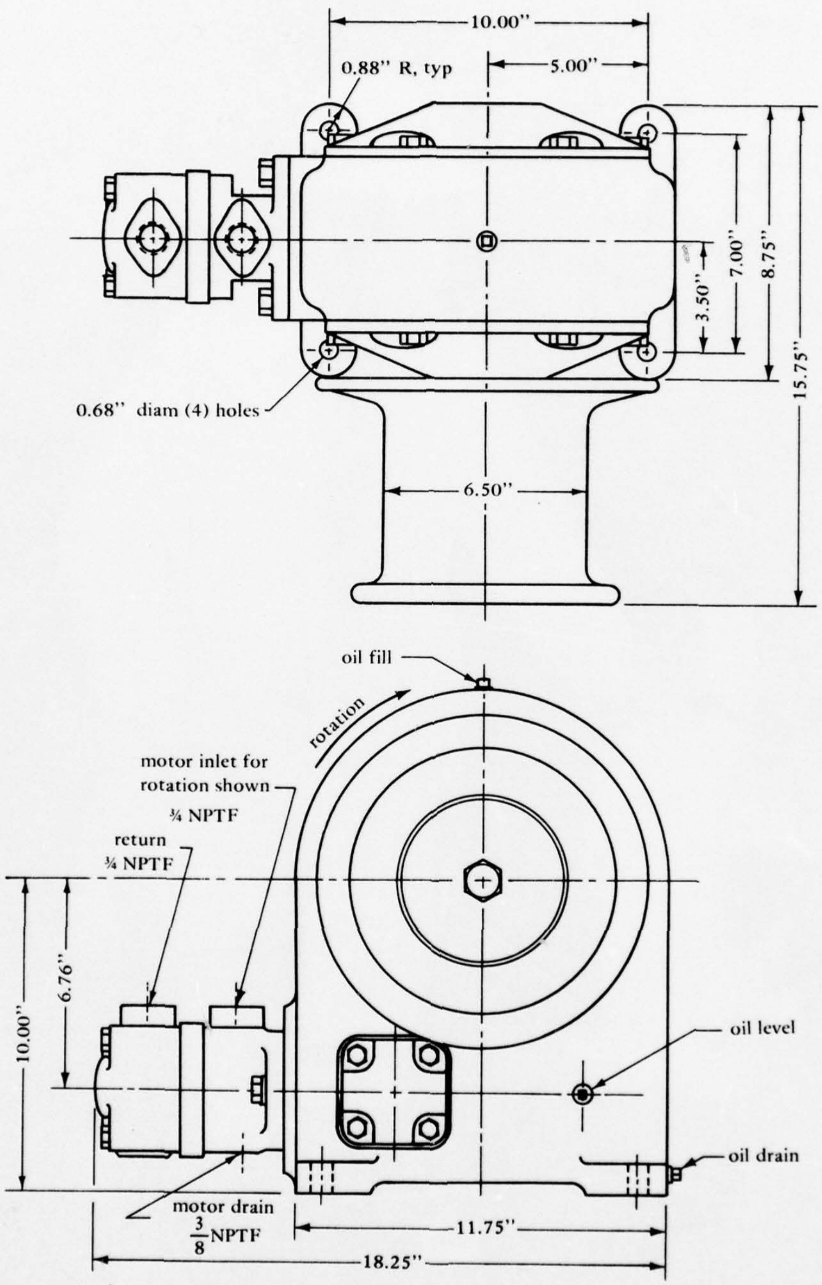

Figure 6. Gypsy winch, physical characteristics (winch drawing, courtesy of MARCO, Ref 2).

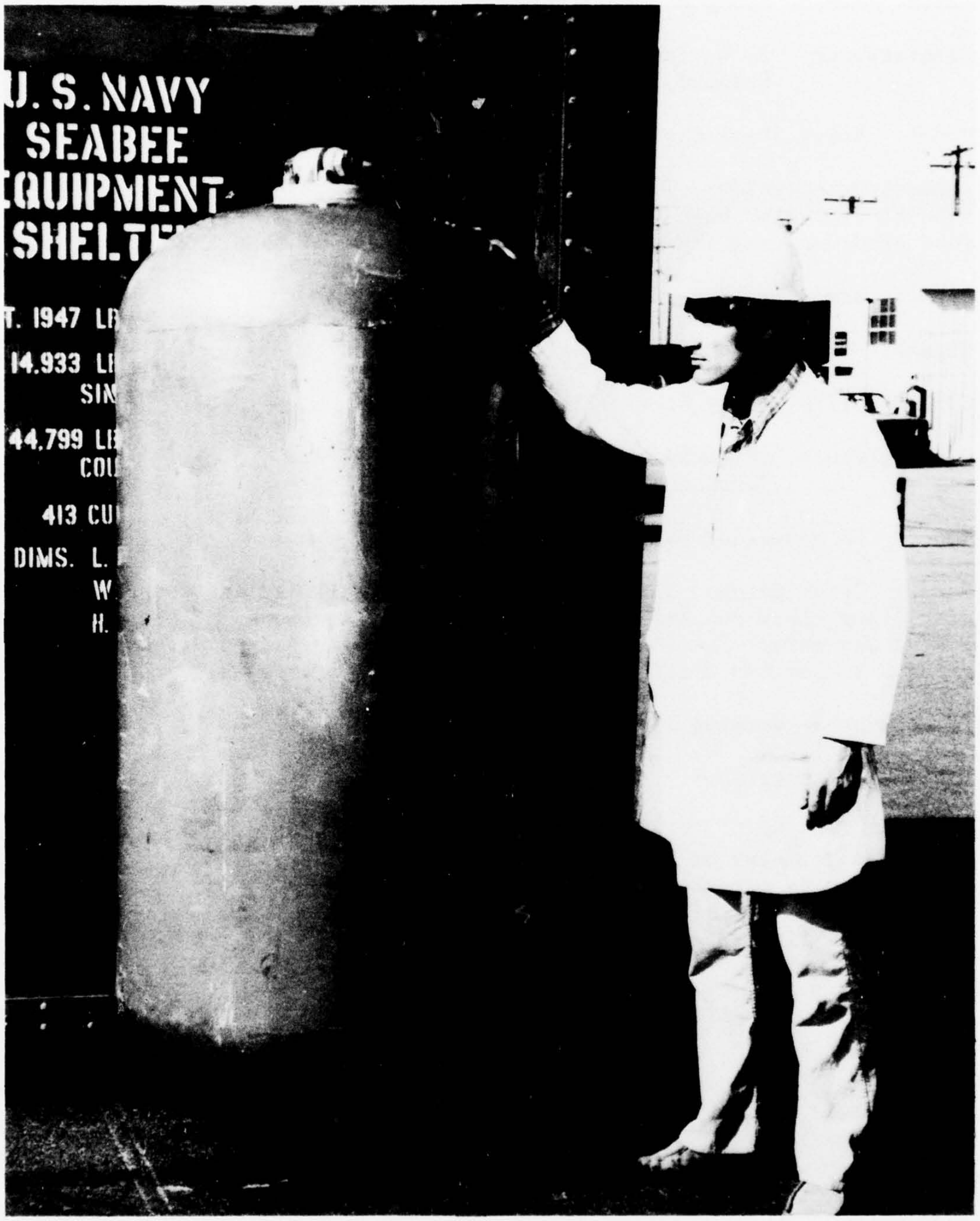

Figure 7. Mooring buoy (cast-urethane covered, closed-cell foam, steel-reinforced).

CHAIN, 1/2-in. Alloy Steel (Figure 8)

Manufacturer: S. G. Taylor Chain Co., Inc.
Hammond, Ind.

Model: Alloy Steel Chain

General Description: Taylor alloy chain (Figure 8) is forged from special analysis, heat treated alloy steel. Alloy steel combines high-load handling capacity with low weight for ease of handling.

Performance: Working load, 11,250 lb.

Physical Description: Weight, 240 lb/80-ft length

COUPLING LINK, Alloy Steel (Figure 8)

Manufacturer: CM Chain
Tonawanda, N.Y.

Model: CM Hammerlok Coupling Links, 1/2 in.

General Description: The CM Hammerlok coupling links are compatible with alloy chain and are composed of two body sections, a load pin, and a stud assembly. The links may be quickly assembled and disassembled using a hammer and drift pin. Figure 8 indicates assembly procedure.

Performance: Working load, 13,000 lb.

Physical Description:

Weight	1.4 lb
Diameter of hole to accept male leg	59/64 in.
Diameter of largest link intended to be used	1 in.

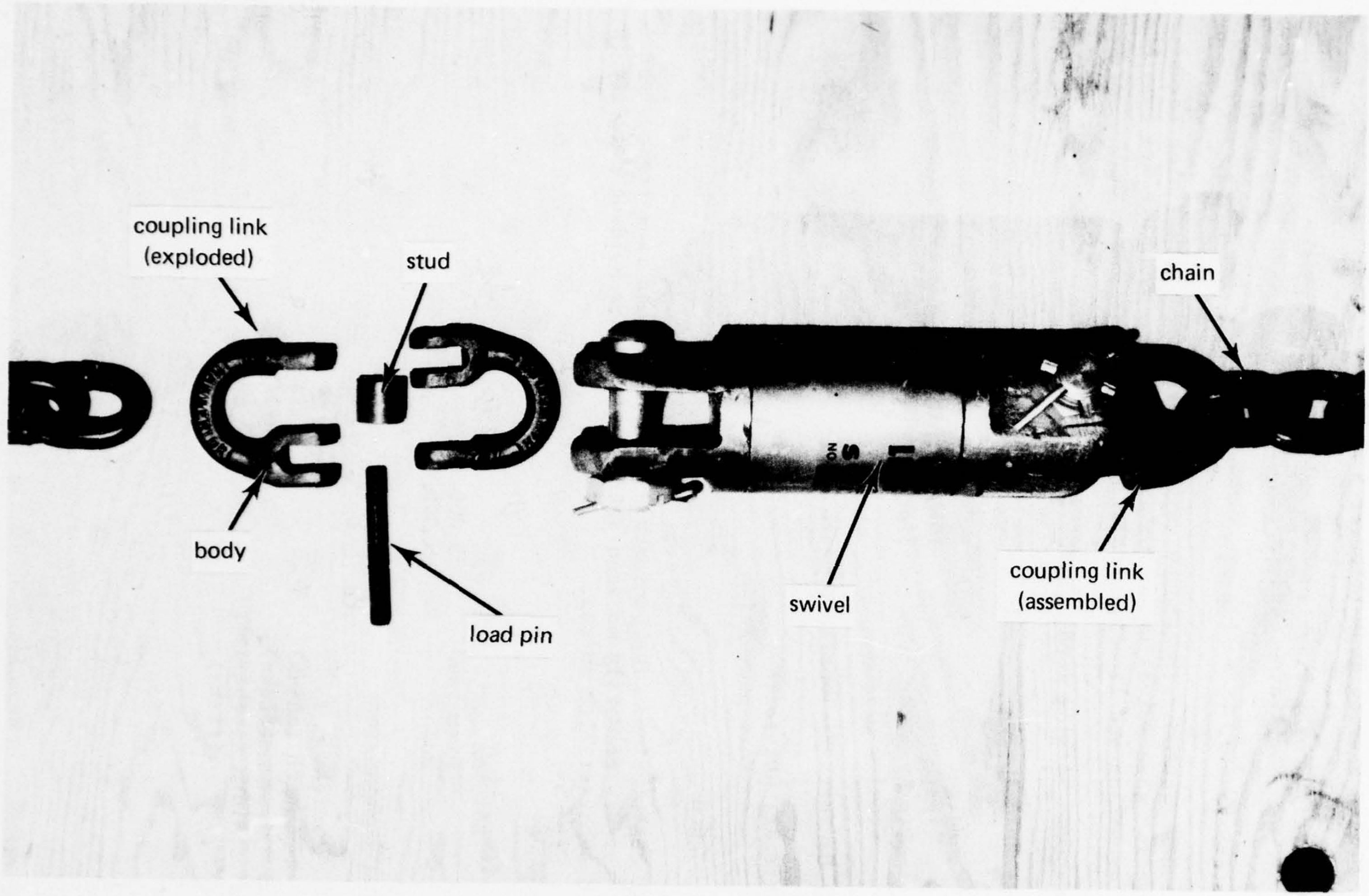

Figure 8. Alloy chain, coupling link, and swivel.

SWIVEL, Sealed Bearing Type (Figures 8 and 9)

Manufacturer: Crosby-Laughlin
Fort Wayne, Ind.

Model: 5-S-2

General Description: The Crosby swivel is equipped with Timken thrust bearings for sure swiveling action at high loads. Bearings are completely sealed by o-ring and lip-type seals.

Performance: Working load, 10,000 lb

Physical Description:

Weight	15.5 lb
Length	10-5/16 in.
Pin Diameter	7/8 in.
Cadmium plated	

ANCHOR, Danforth Hi-Tensile (Figure 1)

Manufacturer: Danforth
Portland, Maine

Model: 200-H

General Description: The Danforth Hi-Tensile anchor is a lightweight anchor for use primarily on sand seafloors. Anchor holding capacity is reduced substantially in mud.

Performance:

Holding force (Ref 4)	
Firm sand	35,000 lb
Mud	5,000 lb

Physical Description:

Weight	200 lb
Length (shank)	57 in.
(fluke)	33-1/2 in.
Width (stabilizer)	46 in.
(fluke)	10 in.

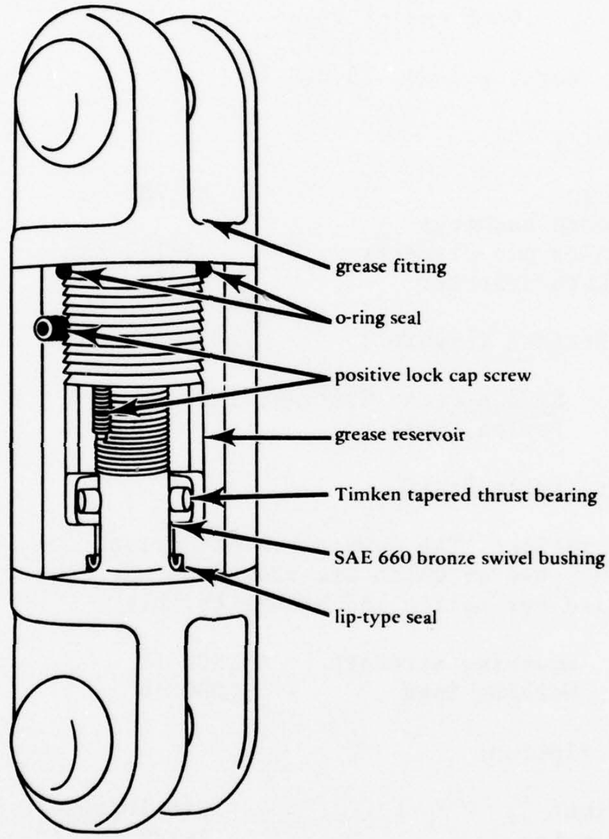

Figure 9. Crosby swivel (drawing reprinted by permission of the Crosby Group, American Hoist and Derrick Co., Ref 3).

SNATCH BLOCK (Figure 1)

Manufacturer: McKissick, Crosby Group
Tulsa, Okla.

Model: 419, Light Champion Type with Shackle

General Description: McKissick snatch block has forged steel shackle, yoke, and sheave. Block opening feature permits quick rope insertion without reeving bitter end of line.

Performance: Working load, 16,000 lb

Physical Description:

Weight	27 lbs
Bronze bushings	
Center pin diameter	1-1/2 in.
Sheave diameter	6 in.

NYLON ROPE, Braided (Figure 1)

Manufacturer: Samson Ocean Systems, Inc.
Boston, Mass.

Model: 2-in-1 Nylon Braid

General Description: The Samson braided nylon rope is provided in 600-ft lengths, two of which are stowed on one drum. Ends are finished with a standard eye splice and bronze thimble.

Performance: Breaking strength 45,000 lb
Working load 9,000 lb

Physical Description:

Weight	216 lb/600-ft length
Diameter	1-1/8 in. (3-1/2 in. circumference)
Braided nylon cover	
Braided nylon core	

System Maintenance

Detailed maintenance and overhaul instructions may be found in the manufacturers' literature provided with the system components. The following maintenance shall be performed after each use to minimize corrosion and prolong component life.

1. Immediately after use, wash all metal components thoroughly with freshwater.

2. If possible, allow components to dry before loading into containers.

3. Wash all metal components again when they arrive at equipment pool (hydraulic quick disconnects and fittings require special attention).

4. Lubricate chain and other fittings with a light oil.

5. Drain and replace lubricants in winches and windlass.

Standard precautions should be taken in caring for the hydraulic system. A discussion of these precautions may be found in the MARCO winch instruction manual provided with the system components.

MISSION PLANNING

This section provides data on predicted mooring system performance to aid the user in planning effective vessel moorings in minimum time. The performance data relate primarily to vessel excursion under a given set of circumstances. Assumptions were made to limit data to representative situations. This data, combined with practical experience, will enable the mooring system user to plan moorings to meet his specific requirements.

Mooring Configurations

Varying degrees of mooring restraint are required for particular missions. For example, inspecting an underwater pipeline would not require precise vessel position control, but lowering and installing a diffuser section at the end of that pipeline would. Moored vessel excursion is primarily controlled by mooring configuration. Figure 10 shows the four basic configurations treated in this guide.* Each configuration best suits a particular positioning requirement and environmental situation.

The two-point mooring is easy to install and provides a suitable mooring when precise positioning is not required.

The three-point mooring may be used for precise positioning when the predominant force (wind or current) is along the vessel centerline. Shifting winds and currents (or beam loads) produce fairly large excursions and limit its effectiveness for precise work.

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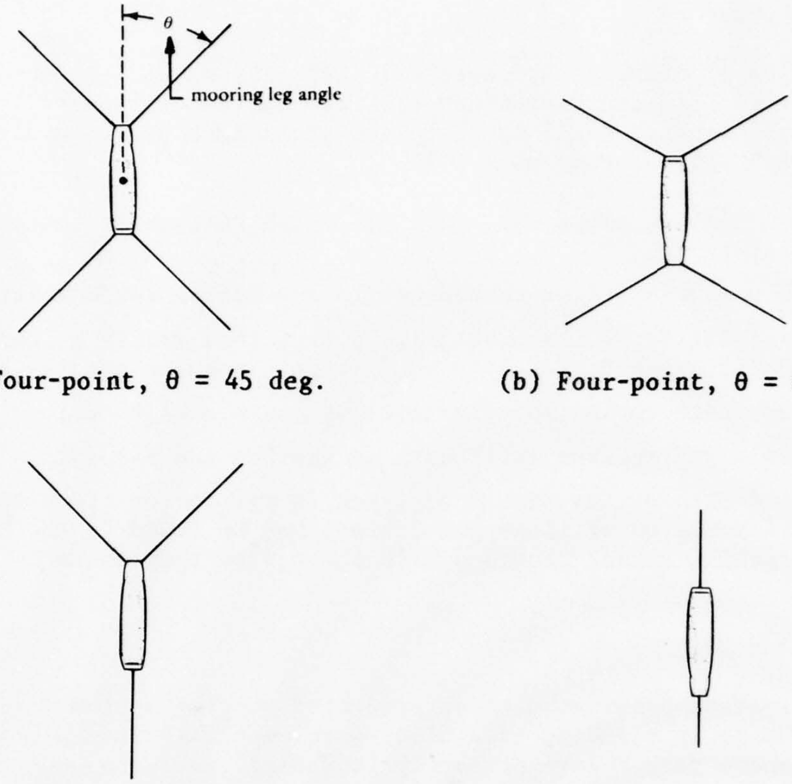
*The single-point mooring is not shown since it provides only a minimum amount of position control. It may be used for a storm mooring or for situations not requiring accurate positioning.



(a) Four-point, θ = 45 deg.

(b) Four-point, θ = 60 deg.

(c) Three-point, θ = 45 deg.

(d) Two-point, θ = 0 deg.

Figure 10. Mooring configurations.

If wind and current directions shift continuously, a four-point mooring is required for precise position control. The mooring leg angles (Figure 10) may be set to counter the predominant force direction. A broadside wind would favor the selection of mooring leg angles closer to 60 deg, while quartering loads might favor an angle of 45 deg. For most applications, mooring leg angles between 30 deg and 60 deg are appropriate (Ref 5). Angles outside these limits tend to allow large vessel excursion for shifting winds or currents.

Vessel excursion depends to a lesser extent on several other factors including water depth and wave activity. These factors are also discussed in this section.

Mooring Leg Composition

A mooring leg composed of a drag embedment anchor, chain, surface buoy, and nylon pennant was normally assumed for vessel excursion calculations. Some excursion data is also presented for all nylon mooring

legs. General information is given for a mooring leg using a tandem clump and a drag anchor. These assumed leg compositions are shown in Figure 11. In all cases a 6-deg mooring line angle with the seafloor was specified at maximum safe working load.

Vessel Excursion

A vessel will not necessarily move directly away from the predominant wind (or current). Instead, wind or current at a slight angle to the vessel's bow will cause the vessel to move in a more beam-wise direction. This effect is especially apparent in the three-point mooring. Figure 12 is a plot of wind (or current) incident angle versus the direction of vessel movement. For the three-point mooring, a wind and current heading 15 deg relative to the bow causes the vessel to move at an angle of almost 70 deg.

Excursion Due to Waves. In the design condition (sea state 4) vessel motion due to waves can be relatively large for the small landing craft (LCM 6, LCM 8, LCU-1610) addressed here. Maximum vessel surge (fore and aft) motion due to waves will occur when the natural frequency of the mooring system approaches the predominant frequency of the incident waves. Changing tension in the mooring lines will change the natural frequency of the mooring. For the landing craft investigated, over the probable range of initial tensions, increased tension moved the mooring natural frequency toward the predominant frequency of the seaway. In this situation, vessel surge will become larger; mooring lines may part or anchors may drag to relieve the stress. Therefore, contrary to what might seem reasonable, increasing the stiffness (tension) of the mooring will not reduce vessel surge in waves. Instead, increased initial tension may increase surging motion or overstress the mooring.

A ship motion program (Ref 6) was used to predict maximum surge motions as a function of mooring stiffness. Table 3 lists predictions for sea state 2 and sea state 4 for three typical ocean construction vessels. The table illustrates that stiffer moorings are likely to increase vessel excursion in waves. For example, in sea state 4, LCM 8 surge may range from 5 to 14 ft, depending on mooring stiffness. A stiff mooring occurs when the chain catenary approaches the shape of a straight line. This happens as water depth is decreased and becomes especially critical for the system in depths less than 50 ft. Large wave-induced excursions are achieved by lifting the chain from the bottom, submerging the mooring buoy and stretching the nylon pennant. Inadequate nylon pennant lengths will result in the mooring being overstressed.

The reader is cautioned that the surge predictions provided in Table 3 are rough approximations. They are included to illustrate the general relationships between sea state, vessel size, and mooring stiffness.

Excursion Due to Wind and Current. Figures 13 through 18 are included to give the mooring planner a feel for the primary variables governing the excursion of a vessel under maximum expected wind and current conditions without waves. The effect of: (1) mooring configuration, (2) water depth, and (3) pre-tension are illustrated. Polar-type

Table 3. Vessel Maximum Surge[a] in Sea State 2 and Sea State 4

Vessel	Soft Mooring (ft) at--		Stiff Mooring (ft) at--	
	Sea State 2	Sea State 4	Sea State 2	Sea State 4
LCU-1610	1.0	4.0	1.0	6.0
LCM 8	2.0	5.0	3.0	14.0
LCM 6	2.0	6.0	7.0	20.0

[a]Largest surge expected in 1,000 waves. Loosely interpreted, there is a 1/1000 chance of exceeding this value.

plots (Figures 13, 15, 17) compare the general excursion patterns of the four basic mooring configurations. These plots are valid only for the assumed 100-ft water depth and 1,000-lb pre-tension. This data may be expanded to other water depths and pre-tensions by referring to Figures 14, 16, and 18.

Although the effect of varying pre-tension is indicated on the plots, practical considerations limit the use of this data. Pre-tension is extremely difficult to accurately measure in the field. An experienced crew may be able to estimate pre-tension by observing prevailing wind and current conditions, buoy submergence, line tautness, and other factors. The maximum pre-tension attainable under ideal conditions, using the winches provided, is probably about 4,000 lb. A pre-tension of 1,000 to 2,000 lb is readily achievable and is appropriate for most conditions.

The polar-type plots in Figures 13, 15, and 17 indicate the position a vessel would take if acted upon by the design wind and current from any direction. This excursion results from straightening of the chain catenary and stretching of the nylon pennant. These plots provide a general comparison of excursions for the four basic mooring configurations considered.

Relative headings of 0, 15, 30, 60, 90, 120, 150, 165, and 180 deg for wind and current acting together were used to obtain these plots. For clarity, in the figures, the incident angles producing the plotted excursions were labeled only on the four-point mooring with $\theta = 45$ deg on Figure 13, curve 2.

The first polar plot on each figure indicates the excursion to be expected with an all-synthetic mooring, compared to the chain and synthetic type. For the cases shown and for most situations, the equilibrium (wind and current only) excursion will be slightly larger with the all-synthetic systems.

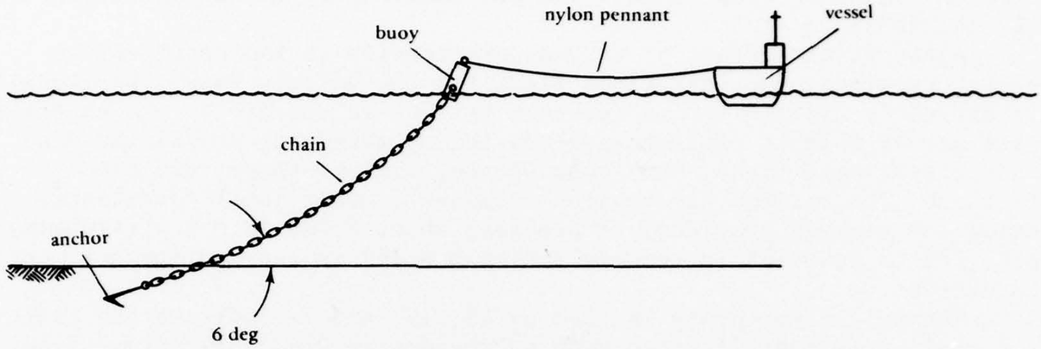
Only excursions for incident angles near 0.0 deg were plotted for the two-point mooring. Greater angles resulted in extreme excursions which fall outside the maximum range of the plots.

A representative wind and current incident angle was assumed for Figures 14, 16, and 18. For example, the incident angle producing the largest vessel excursion was assumed for the four-point mooring. This is reasonable since the four-point mooring will probably be used in situations when a shifting wind or current direction is expected.

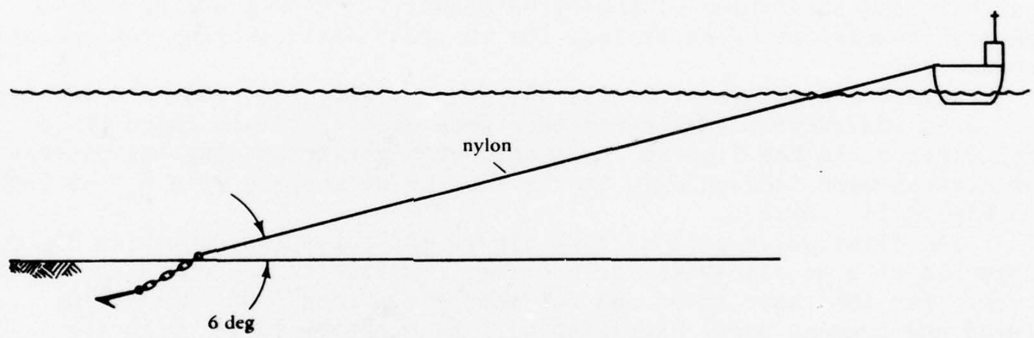
The worst case incident angle was not chosen for the three-point mooring. The three-point mooring would probably not be used when both precise positioning is required and shifting wind direction is possible. Instead, the three-point mooring will most likely be used when the wind and current direction is within a few degrees of the bow or when precise positioning is not required. Therefore, an angle of 15 deg was chosen as representative.

The two-point mooring was not included in these plots since it will most likely not be used in any situation requiring precise position control.

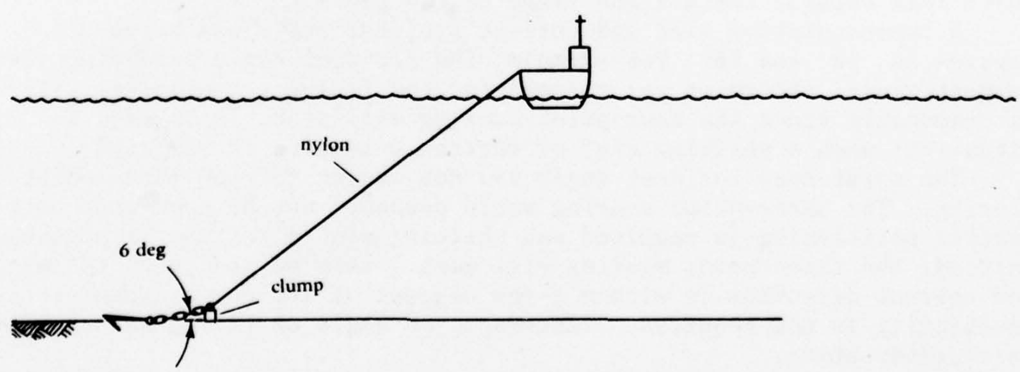
The excursion for a four-point, all-synthetic mooring was plotted for comparison with the chain-pennant system. These curves show that high pre-tensions are not as effective in the all-synthetic system. Pre-tensions above 2,000 lb are probably not warranted.



(a) Anchor-chain-buoy-synthetic.



(b) Anchor-synthetic.



(c) Anchor-clump-synthetic.

Figure 11. Assumed mooring leg compositions.

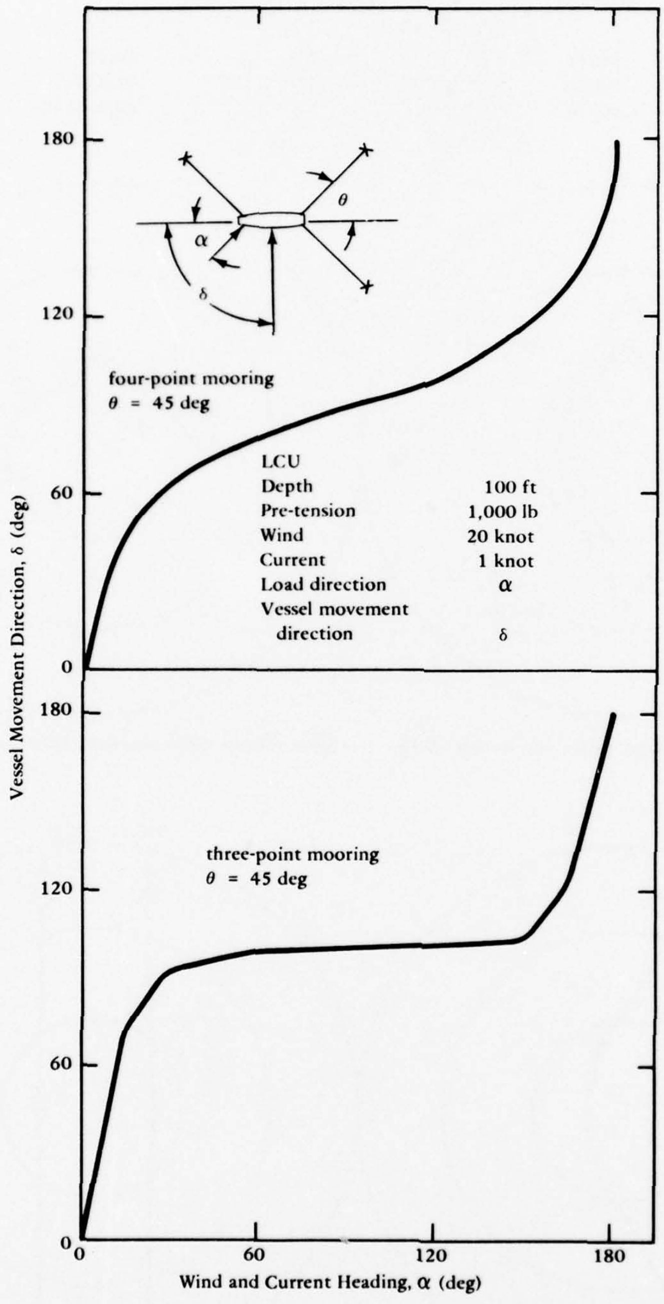
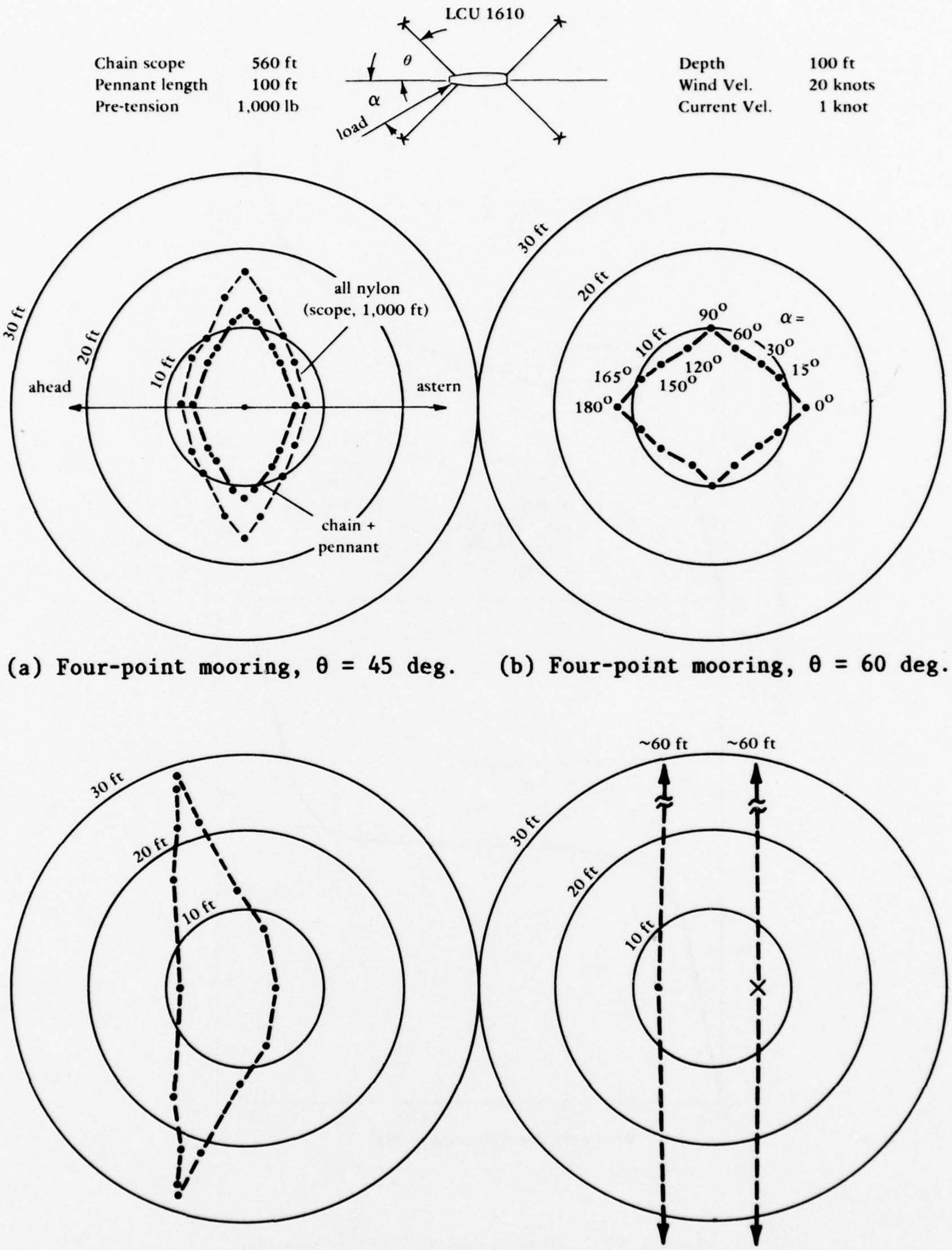


Figure 12. Direction vessel moves for a given wind and current direction.



(a) Four-point mooring, θ = 45 deg. (b) Four-point mooring, θ = 60 deg.

(c) Three-point mooring, θ = 45 deg. (d) Two-point mooring, θ = 0 deg.

Figure 13. LCU-1610, excursion for omnidirectional 20-knot wind and 1-knot current.

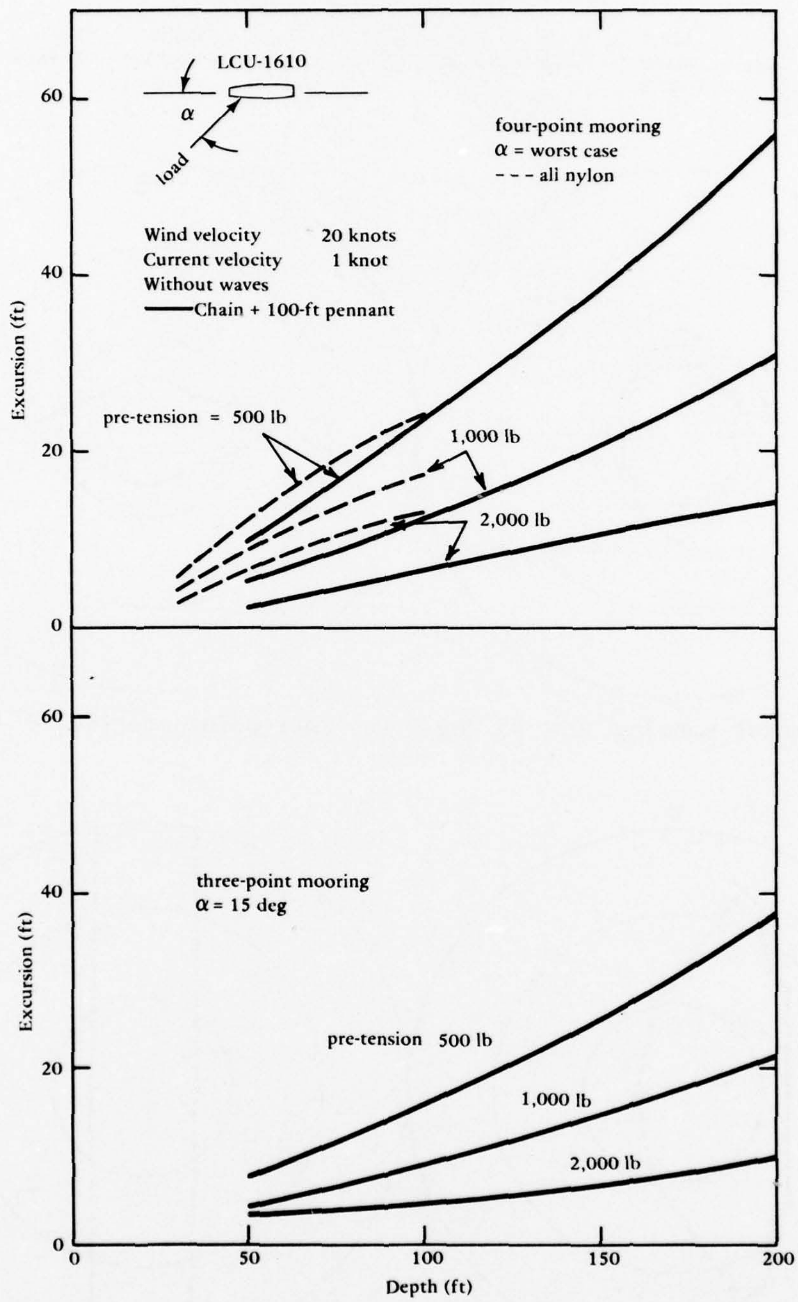
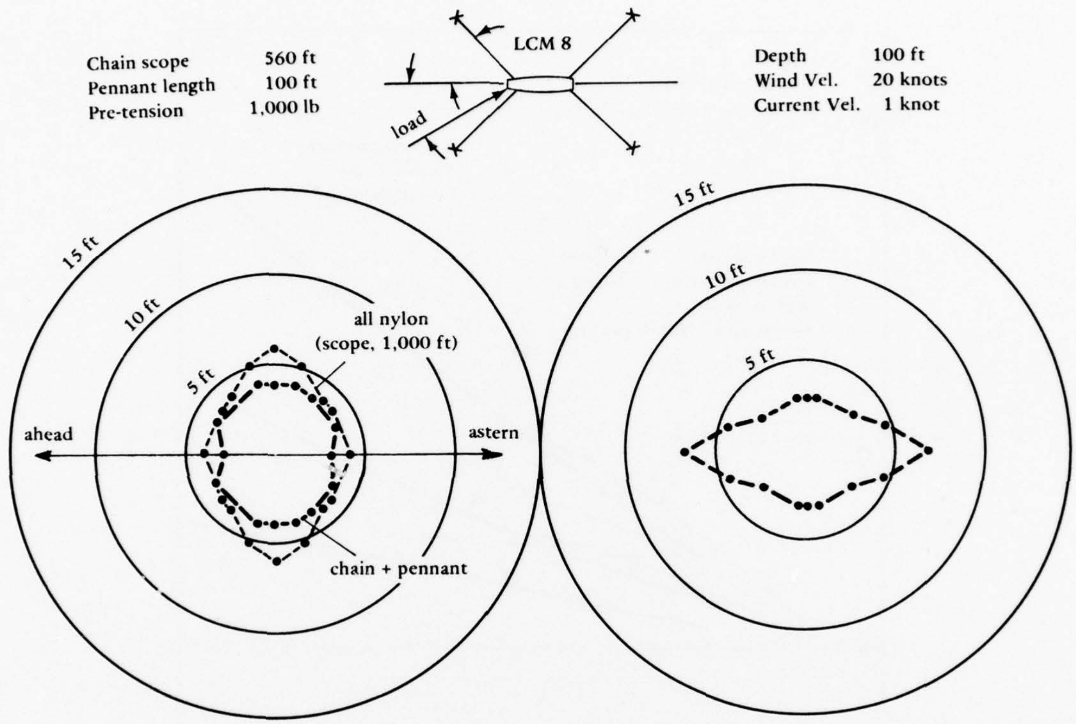
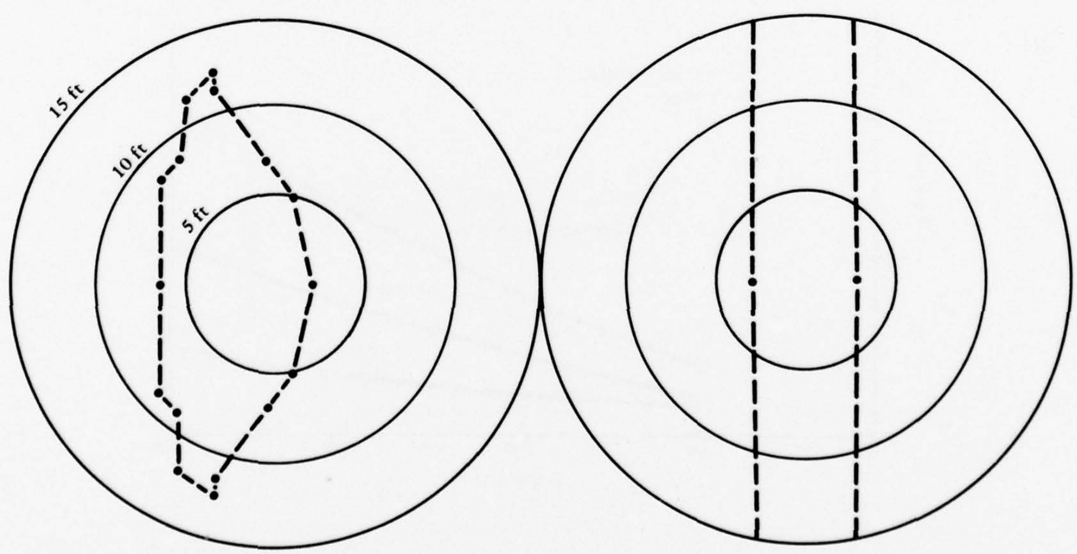


Figure 14. LCU-1610, effect of depth and pre-tension on vessel excursion.



(a) Four-point mooring, θ = 45 deg. (b) Four-point mooring, θ = 60 deg.



(c) Three-point mooring, θ = 45 deg. (d) Two-point mooring, θ = 0 deg.

Figure 15. LCM 8, excursion for omnidirectional 20-knot wind and 1-knot current.

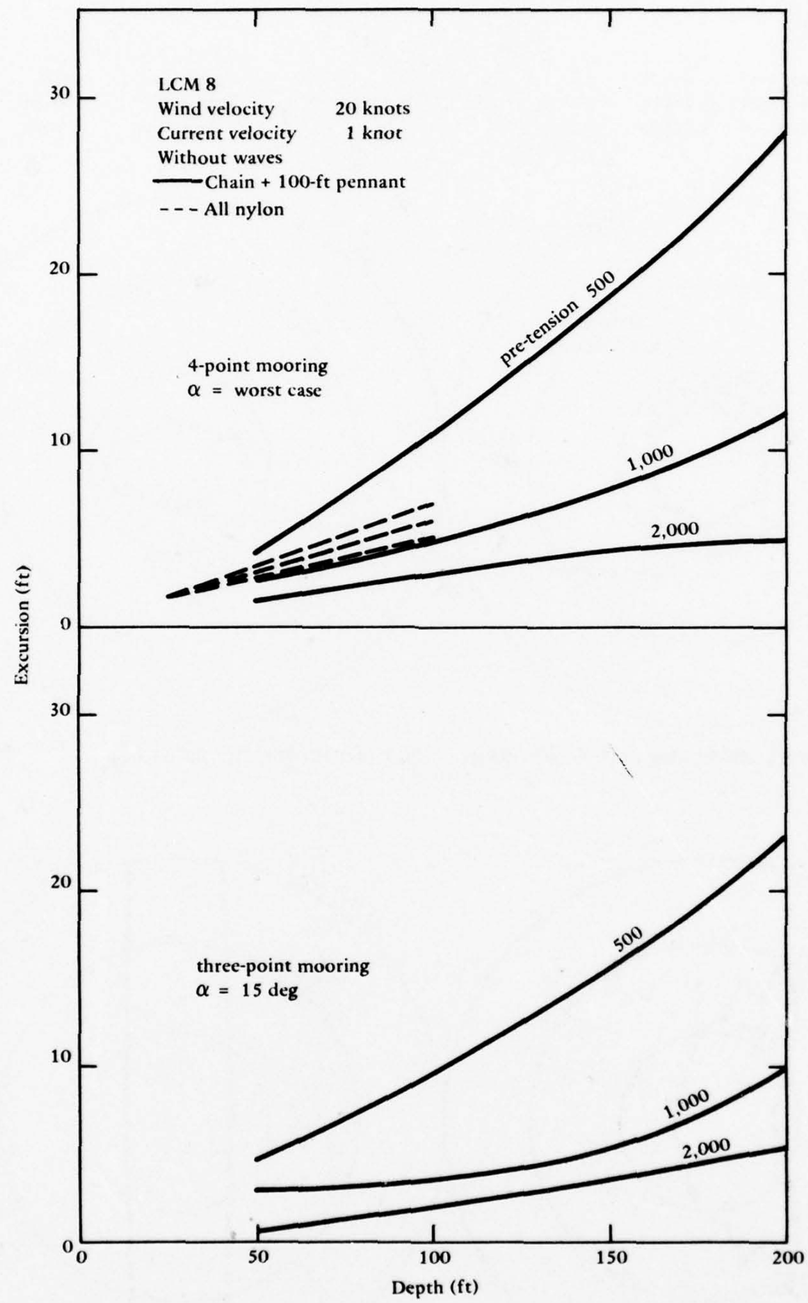
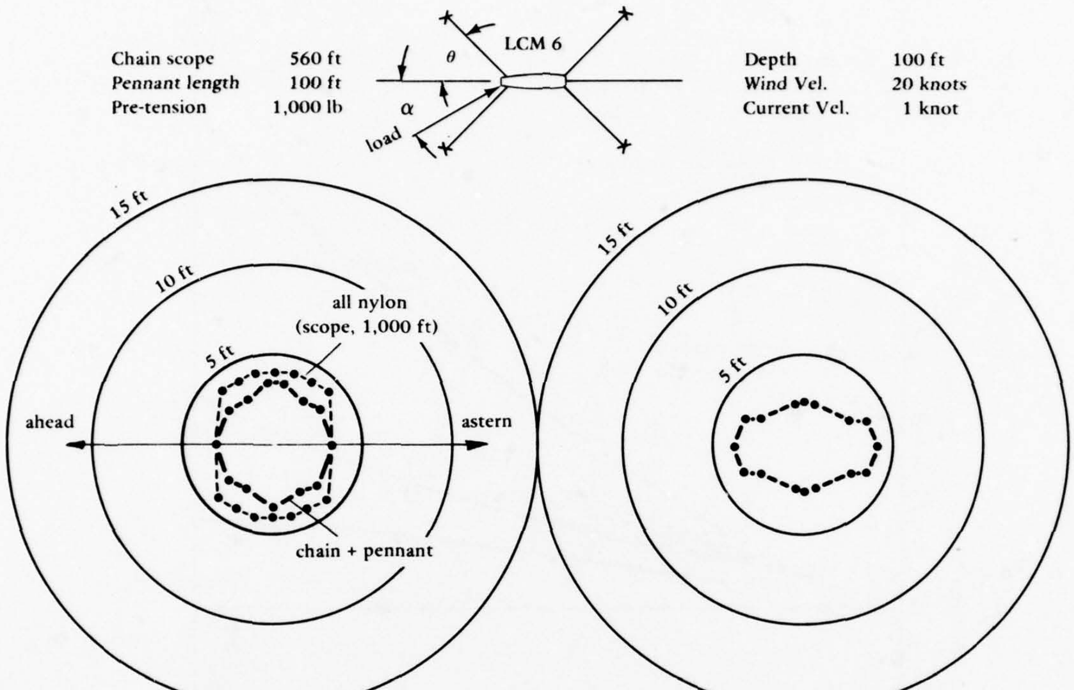
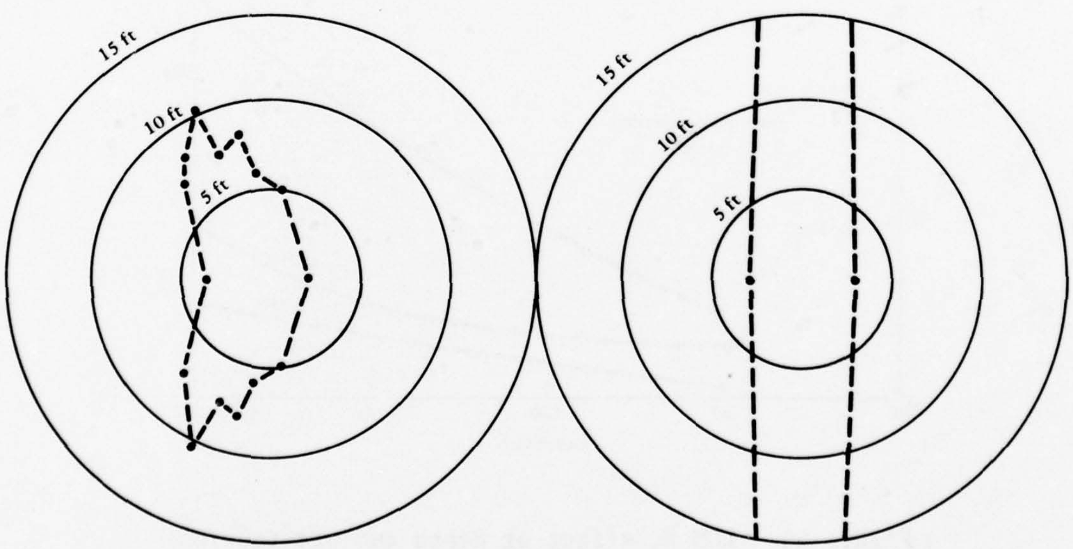


Figure 16. LCM 8, effect of depth and pre-tension on vessel excursion.



(a) Four-point mooring, θ = 45 deg. (b) Four-point mooring, θ = 60 deg.



(c) Three-point mooring, θ = 45 deg. (d) Two-point mooring, θ = 0 deg.

Figure 17. LCM 6, excursion for omnidirectional 20-knot wind and 1-knot current.

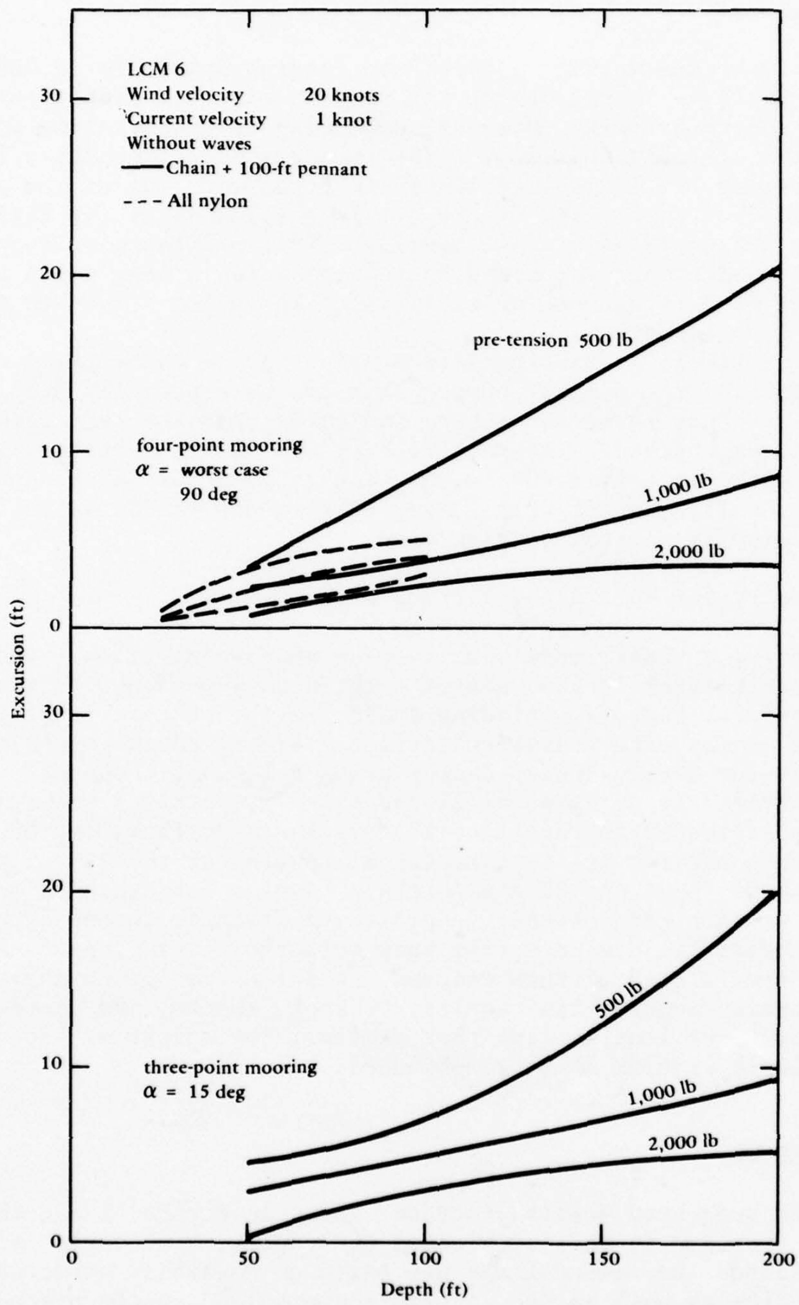


Figure 18. LCM 6, effect of depth and pre-tension on vessel excursion.

Safe Working Load

The maximum safe working load of the mooring system is 10,000 lb. As shown in Table 4, forces due to the 20-knot wind and 1-knot current will not exceed this limit. However, depending on the severity of wave action and the ultimate capacity of the anchor, the safe working load could be exceeded. This is more likely to occur with one of the smaller vessels in shallow water (<50 ft deep). In shallow water the chain becomes taut and produces a stiff mooring. This stiffness increases surge motion, which may overextend the chain; using a long nylon pennant is one way of minimizing mooring stiffness. The nylon stretches to absorb wave-induced motions.

A rough estimate of mooring-line tension may be gained from observing submergence of the mooring buoy. This can be especially helpful in shallow water. Buoy submergence here indicates that the safe working load is being approached. The mooring buoy will fully submerge at line tensions of approximately 7,000, 4,000, and 2,500 lb in water depths of 50, 100 and 200 ft, respectively. Buoy submergence versus water depth and line tension is plotted in Figure 19.

Mooring Geometry for Work Along a Track

Frequently, a vessel must work over an underwater track. The maximum possible track length using the chain-buoy-pennant leg composition depends on several factors including chain length, pennant length, and mooring line angles with vessel centerline. Figure 20 indicates maximum track lengths for various water depths using a 1,000-ft pennant. The mooring is assumed to be symmetrical about the midpoint of the track. Mooring line angles at the start of the track are 30 (bow) and 60 deg (stern). Since the mooring is symmetrical, angles at the end of the track will be 60 (bow) and 30 deg (stern). Angles less than 30 or more than 60 deg are not recommended. Approximate distance to the anchor is the sum of horizontal distance from buoy to anchor plus pennant length. The anchors are located at this distance at the angles given above.

To determine mooring line angles, pennant lengths, and anchor locations for track lengths less than maximum, the graphical procedure shown in Example Problem 3* is recommended.

DESIGN PROCEDURE

With the suggested design procedure given in Figure 21 and the information provided in this section of the report, a suitable mooring may be specified. Recommendations are based on generally accepted mooring practice as well as the information provided in the preceding sections of this guide. Example problems are included to highlight particular points and to demonstrate the design procedure suggested.

*Examples are presented in the following section of this report.

Table 4. Design Forces

Vessel	20-Knot Wind + 1-Knot Current Force (lb)	Total Force[a,b] (lb) at Depth--	
		< 175 ft	> 175 ft
LCU	4,500	10,000	7,000
LCM 8	1,500	10,000	7,000
LCM 6	1,200	10,000	7,000

[a]Sea state 4 (H 1/3 = 7.0 ft).

[b]Assumes that recommended minimum pennant lengths are used (see DESIGN PROCEDURE section).

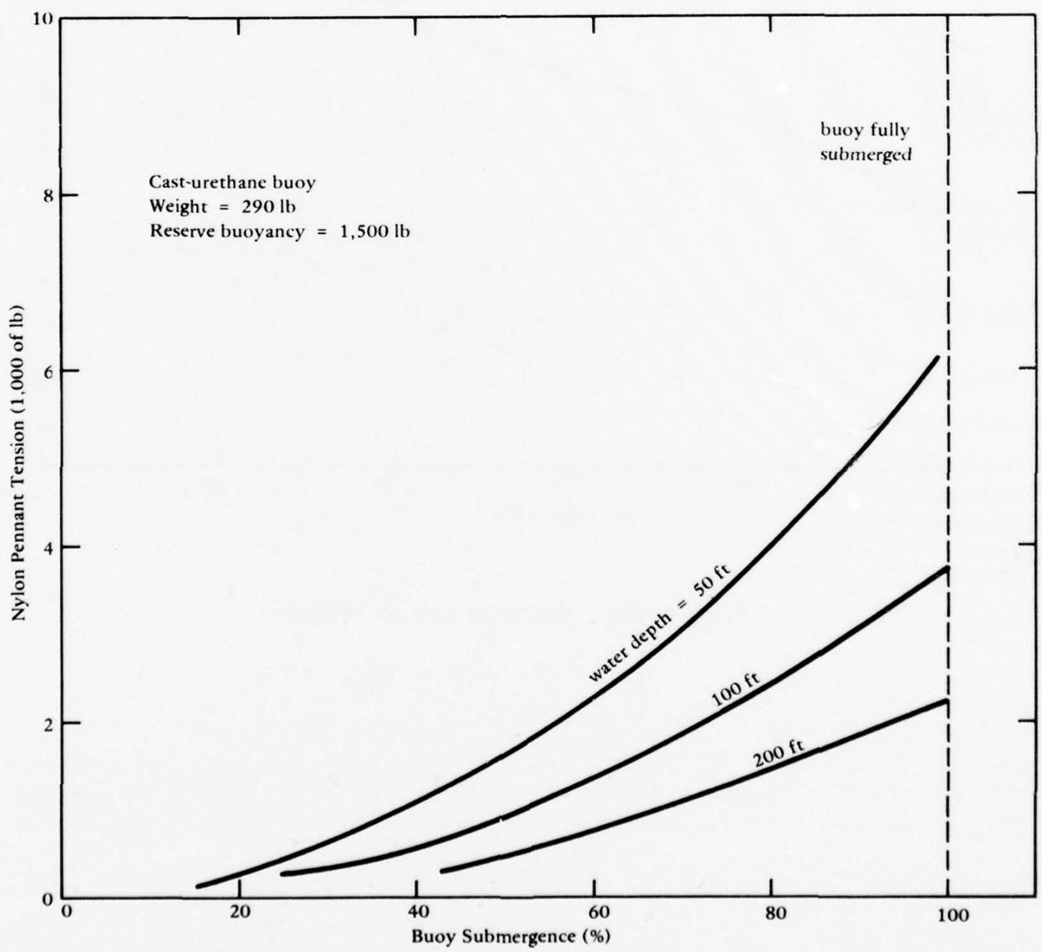


Figure 19. Buoy submergence versus nylon pennant tension.

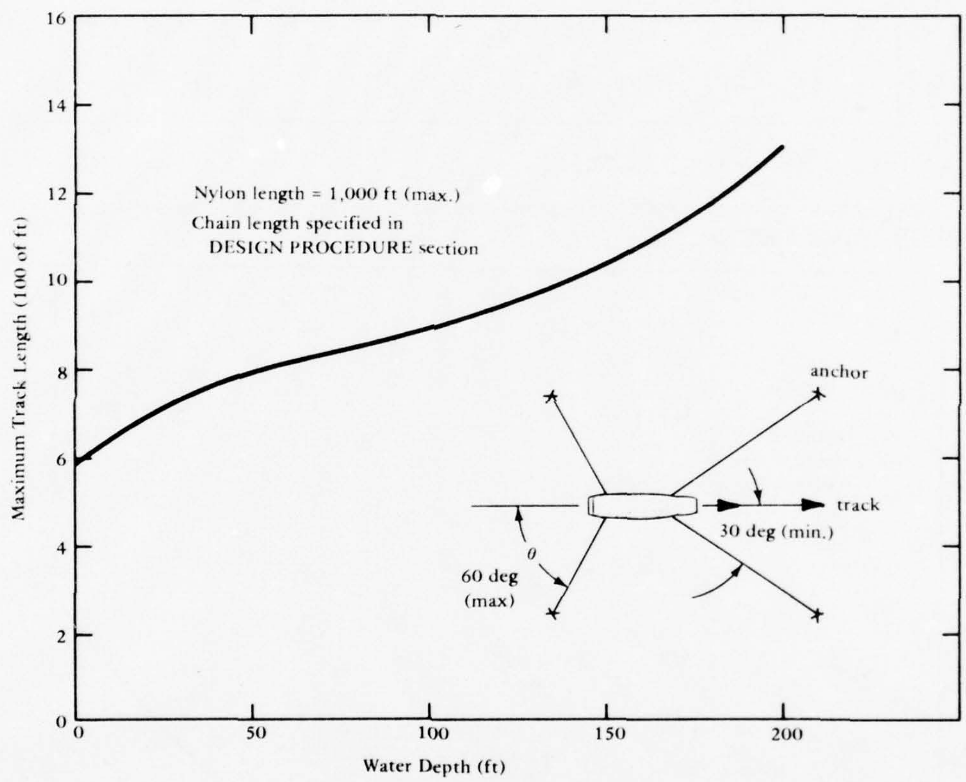


Figure 20. Maximum track length.

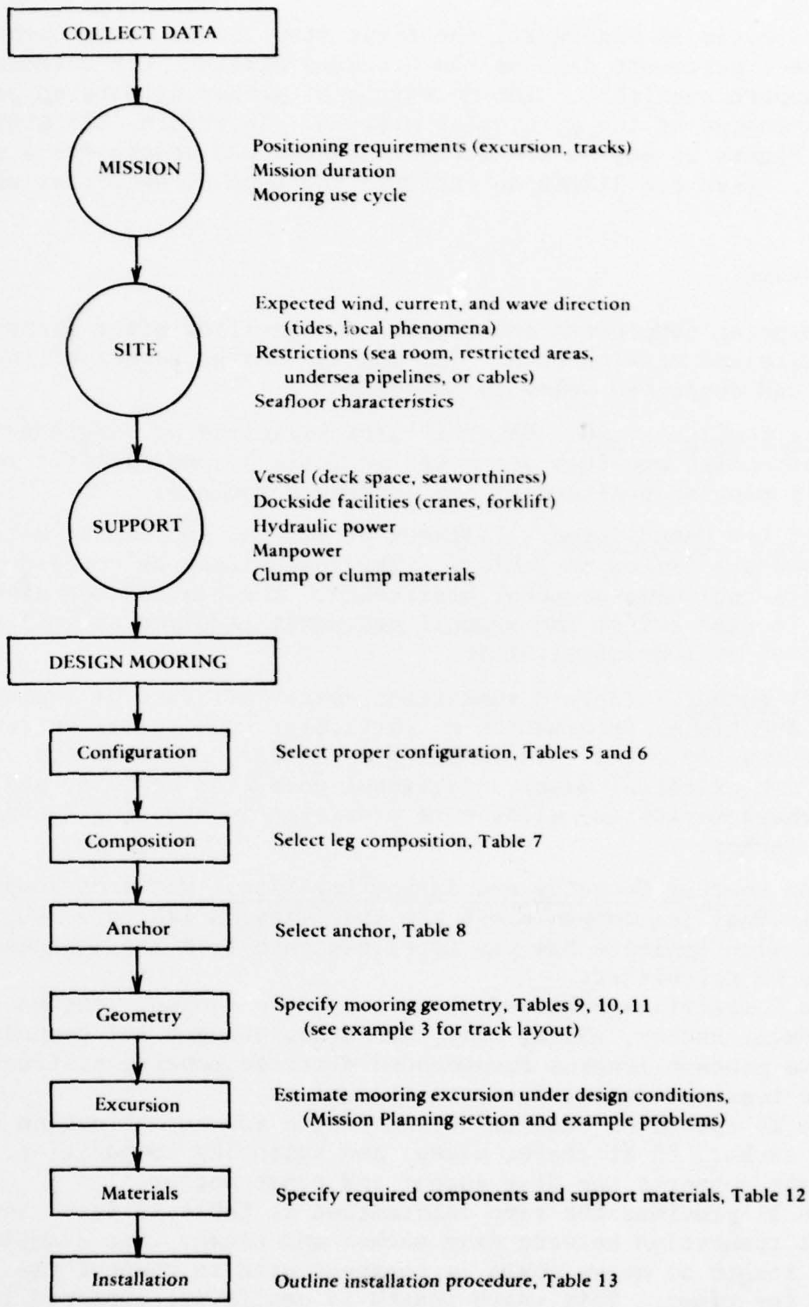


Figure 21. Mooring design procedure.

Collect Data

As indicated in Figure 21, the first step in the design procedure is to collect pertinent data on the proposed mission, the intended site, and the support available. The necessity of gathering data on particular items will depend on the particular mission. Therefore, the items listed in Figure 21 may be too much or perhaps not enough for a given situation. Items are listed to indicate the type of data that should be considered.

Design Mooring

The mooring components and layout are specified after gathering required site and mission data. The mooring design sequence listed in Figure 21 and described below is suggested.

Select Configuration. General characteristics of single-point through four-point moorings are noted in Table 5, and specific recommendations for precise positioning are listed in Table 6.

Select Leg Composition. Features of several individual mooring leg compositions are listed in Table 7. The composition selected depends on many factors including personal preference. The composition used will determine to some extent the support equipment required as well as the difficulty of system installation.

Select Anchor. Table 8 summarizes characteristics of commonly used anchors. Additional information on particular anchors may be found in the references indicated. In choosing an anchor, sediment type and thickness are essential data. Additional data (for example, sediment strength characteristics) allow more precision in choosing the most efficient anchor.

Define Mooring Geometry and Anchor Location. Required scopes for three individual leg compositions are specified in Tables 9, 10, and 11. The tables also indicate how the total distance from mooring center to anchor may be calculated.

Table 9 specifies required chain scope and pennant lengths for the drag embedment anchor, chain, buoy, and nylon pennant leg composition. The minimum pennant lengths recommended decrease mooring stiffness to limit line tensions during open sea operations.

Table 10 specifies required nylon length for a combination drag embedment anchor, 80 ft chain, clump, and nylon leg composition. The chain length connects the drag anchor and clump anchor.

Table 11 provides the same information as Table 10 for a leg with a very short connection between drag anchor and clump. For example, a 6 to 8-ft length of heavy chain is commonly used to connect the drag anchor to the clump. This chain length is negligible compared to nylon scope and was ignored in Table 11.

Specify Materials. Required materials for a single mooring leg are given in Table 12. Note that a hydraulic power source is required to operate the winches and for anchor windlass. Appropriate lifting equipment is also required to position the windlass. Clump weights and corresponding nylon scopes are specified in Tables 10 and 11.

Table 5. Configuration Summary

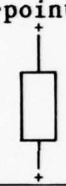
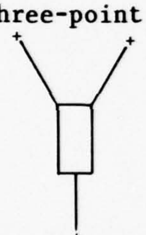
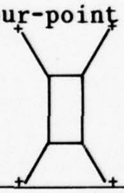
Configuration	Positioning Capability	Remarks
Single-point 	Minimal; large excursion as vessel swings to align with wind or current; fishtailing or tacking occurs	Exerts minimum force on anchor; best for heavy weather or transient mooring
Two-point 	Minimal; limits swing somewhat; large excursions for loads slightly off centerline	Not for precise positioning; suitable for transient mooring with limited sea room
Three-point 	Good if load ±15 deg of bow; moderate for loads from other angles	Meets needs for most situations not requiring optimum position control; inadequate for precise positioning in shifting wind or current
Four-point 	Good for loads from any direction	Best for situations where wind or current direction may shift and precise positioning must be maintained; leg angles are chosen to suit conditions

Table 6. Configuration Recommendations for Precise Positioning Based on Wind and Current Direction[a]

Wind and Current Direction (deg)	No. of Legs	Leg Angle (deg)
0-15	3	45
15-30	4	45
> 30	4	60
Variable	4	30 to 60

[a]See illustration for definition of angles.

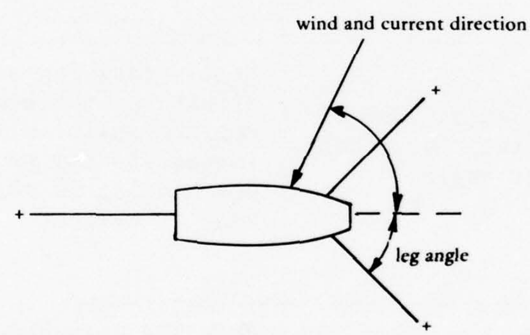


Table 7. Summary of Leg Composition Features

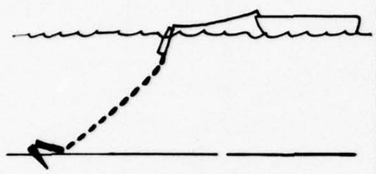
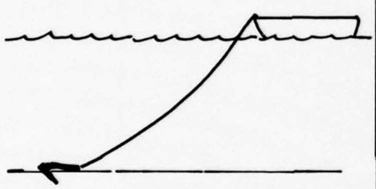
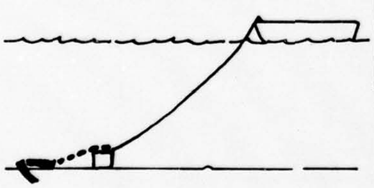
Composition	Features
chain-buoy-nylon 	May be combined with clump to reduce scope Heavy, requires wildcat to handle chain Good energy absorption Good abrasion resistance, withstands rough treatment
all-nylon 	Low weight, easy to handle Good energy absorption Poor abrasion resistance, must be handled carefully Chain length must be added to embed anchor Requires long scopes and adequate sea room Suitable for use with uplift-resisting anchor on shorter scopes
nylon-clump 	Reduced scope possible Heavy clump must be obtained and lowered to bottom Less energy absorption, stiffer mooring Poor abrasion resistance (nylon)

Table 8. Summary of Anchor Characteristics

Anchor Type	Application	Features	Required Site Data	Remarks	For Additional Information
Drag-- (Navy Stock-less)	sediment; cobbles, boulders, coral, rock	Does not bury deeply; relatively low holding-capacity-to-weight ratio; applicable to wide range of seafloors	Depth of sediment, soil type, areal variability; general characteristics of nonsediment seafloors	Easy recovery makes it good for temporary moorings; capacity decreases rapidly when uplift forces are applied	Ref 7
Burial (STATO, LWT, Danforth)	sediment; adequate sediment depth required for deep burial	High holding-capacity-to-weight ratio; capacity depends on deep burial in sediment; burial depth sensitive to fluke angle and soil anomalies	As above	STATO has adjustable fluke for use on sand or clay; may be difficult to recover when buried deeply; uplift decreases capacity	Ref 7 and 8
Deadweight (Clump, mushroom)	sediment; minimal thickness required	Very low holding-capacity-to-weight ratio; bulky; horizontal capacity may be almost nil on fluid mud type of seafloors; does not bury deeply	As above; seafloor slopes greater than 10 deg have significant effect on capacity and stability	May be used to resist uplift forces (clump)	Ref 7, 8, and 9
Drag anchor (or burial) and deadweight combination	sediment	Clump resists uplift and drag anchor resists horizontal load	As above	Used to reduce mooring line scope	Ref 7

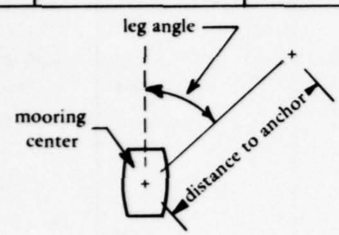
continued

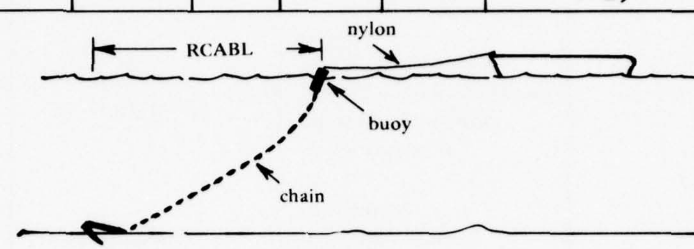
Table 8. Continued.

Anchor Type	Application	Features	Required Site Data	Remarks	For Additional Information
Piling (drilled in or driven)	sediment, coral, limestone, rock	Resists uplift forces; piling in hard coral or limestone must be drilled in and grouted	Sediment thickness and strength at anchor location; rock strength	Expensive; time-consuming, and relatively permanent. Typically used where very high capacity is required	Ref 7, 8, 9, 10, 11
Jetted-in Cone or Deadweight	sand	Jetting action buries anchor; diver installation practical	Sediment type and thickness	Relatively time consuming, requires pumps and jetting hoses; simple constructions feasible	Ref 8
Explosive Embedment	sediment coral or soft rock	Resists uplift forces; high holding-capacity-to-weight ratio due to deep anchor burial.	Sediment thickness, coral strength	Economical alternative to piling; special ordnance handling precautions required; not recoverable	Ref 8
Rock Bolt	hard rock, coral	Resists uplift; installed by divers; grouted or ungrouted models are available	General size and characteristics of rock; rock strength	Economical alternative to piling for rock seafloor	Ref 8 and 12

Table 9. Required Chain Scopes and Nylon Pennant Lengths

Depth (ft)	Recommended[a] Scope (ft)	Scope/ Depth (ft/ft)	Shots (80 ft)	Minimum Pennant[b] (ft)	RCABL[c] (ft)	Distance to Anchor for--			
						LCU (ft)	LCM 8 (ft)	LCM 6 (ft)	Other Vessels[d]
0-50	400	8	5	250[e]	393	720	690	680	RCABL
51-75	480	6.4	6	200	468	745	715	705	+
76-100	560	5.6	7	150	541	770	740	730	pennant length
101-125	640	5.1	8	100	612	790	760	750	+
126-150	720	4.8	9	100	686	865	835	825	anchor setting distance
151-175	800	4.6	10	100	758	935	905	895	+
176-200	800	4.0	10	50	830	960	930	920	(vessel length ÷ 2)





[a]Horizontal design force = 10,000 lb at depths <175 ft, 7,000 lb at depths >175 ft.

[b]Minimum length required to minimize mooring response to waves; for sheltered water, shorter pennants may be used.

[c]RCABL = Horizontal distance from buoy to anchor at a pre-tension of 2,000 lb.

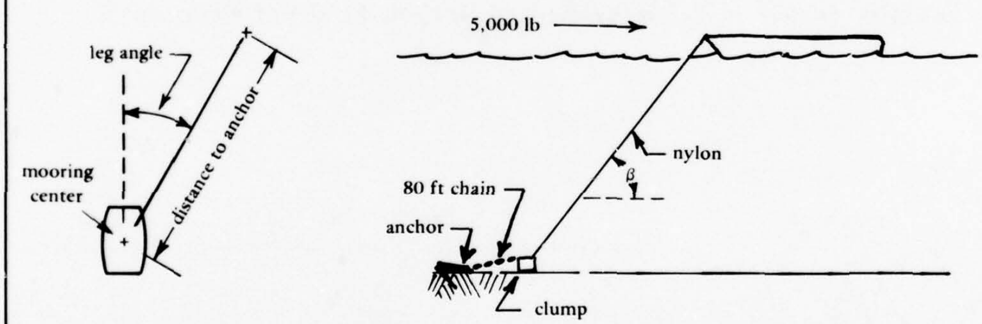
[d]See illustration.

[e]All-synthetic systems should be considered at these depths.

Table 10. Required Synthetic Scope With Chain[a]

(Horizontal force, 5,000 lb; chain length, 80 ft; chain weight, 3.0 lb/ft; chain angle at drag embedment anchor, 6 deg; for exposed areas, minimum nylon length, 250 ft)

Water Depth (ft)	Nylon Scopes (ft) With Submerged Clump Weight (lb)[b] of--						
	0	100	200	300	500	1,000	2,000
25	100	90	80	75	60	45	30
50	260	230	210	190	160	120	80
75	430	385	350	320	265	195	135
100	590	525	475	430	370	270	190
150	925	820	740	675	580	420	280
200	1,260	1,100	1,000	900	780	570	380
cos β	0.99	0.98	0.98	0.98	0.97	0.94	0.87



[a]Distance to anchor = nylon scope x cos β
+ chain length
+ vessel length ÷ 2

[b]Weight in air ≈1.7 x submerged weight (for 150 pcf concrete)

Table 11. Required Synthetic Scope Without Chain[a]

(Horizontal force, 5,000 lb; chain length negligible, assumed 0; line angle at drag embedment anchor, 6 deg; for exposed areas, minimum nylon length 250 ft)

Depth (ft)	Nylon Scope (ft) With Submerged Clump Weight (lb)[b] of--						
	0	200	400	600	800	1,000	2,000
25	240	175	135	115	100	85	55
50	475	350	275	230	195	175	110
100	960	700	550	455	390	340	220
150	1,435	1,050	825	680	585	515	330
200	1,915	1,400	1,095	910	785	685	440
cos β	0.99	0.99	0.98	0.97	0.97	0.96	0.89

[a]Distance to anchor = nylon scope x cos β + (vessel length ÷ 2)

[b]Weight in air ≈ 1.7 x submerged weight (150 pcf concrete)

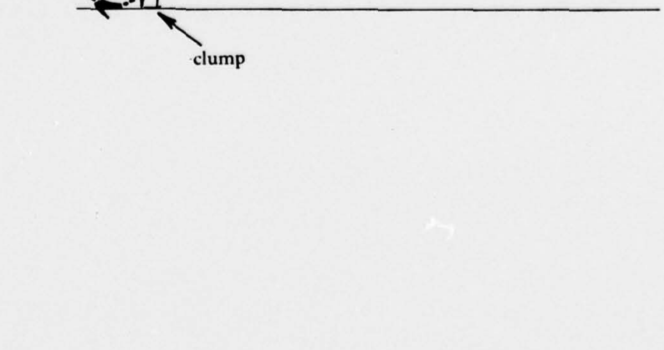


Table 12. Bill of Materials[a]

(Required in each case: one anchor, one buoy[b], one windlass or winch[c], one swivel, five shackles, and two snatch blocks[b].)

Depth	Chain (Shots)	Connect Link	Nylon (ft)
Chain-Buoy-Pennant Leg			
0-50	5	7	250
51-75	6	8	200
76-100	7	9	150
101-125	8	10	100
126-150	9	11	100
151-175	10	12	100
176-200	10	12	50
Synthetic Leg (Without Clump)[d]			
0-50	1	2	500
51-75	1	2	750
76-100	1	2	1,000
101-125	1	2	1,200
126-150	1	2	1,450
151-175	1	2	1,700
176-200	1	2	2,000

[a]For several legs, multiply values by the number of mooring legs.

[b]Might or might not be required, depending on the situation.

[c]Windlass required for handling chain; hydraulic power required for winch or windlass.

[d]Refer to Table 10 or 11 to find nylon scope with clump weight.

Outline Installation Procedure. A suggested installation procedure is outlined in Table 13. This procedure assumes that only one vessel is available to install the mooring. Procedures for spread-mooring installation when an additional vessel is available are described in the Harbor and Coastal Facilities Design Manual (DM-26) (Ref 7).

Example Problems

Three example problems follow to highlight the information in this section. The problems show that answers to every situation are not found in this guide. However, the information presented may be used as a tool to work out reasonable solutions to similar situations not specifically covered. The solutions provided were chosen to illustrate certain points and do not represent the only solutions for the given situations.

Example 1. This problem illustrates selecting a mooring requiring precise position control in an exposed area.

1. Objective: Place outfall diffuser section
2. Given: Water depth - 100 ft (average)
   Vessel - LCM 8
   Limiting environmental conditions:
      Wind velocity - 20 knots
      Current velocity - 1 knot
      Wind and current direction variable
   Bottom material - firm sand with 50-ft thickness
   Maximum vessel excursion acceptable - 20 ft
   Location - exposed to wave action
3. Find: (a) Appropriate mooring configuration
   (b) Leg composition and anchor
   (c) Mooring geometry (location of anchors)
   (d) Probable maximum excursion
   (e) Materials required
4. Solution:

   (a) Configuration, Tables 5 and 6. A four-point mooring, $\theta = 45$ deg is selected. The four-point mooring is selected to minimize excursion for a shifting wind and current. Figure 15 indicates that leg angles of 45 deg minimize LCM 8 excursion for variable wind and current direction.

   (b) Leg Composition, Tables 7 and 8. Chain-buoy-pennant and burial anchor. The system is rugged, gives good position control, and allows easy exit and entry from mooring.

Table 13. Installation Procedure

No.	Procedures
1.	Define locations of mooring center and anchors using: a. Geographic or electronic reference or b. Small diameter measuring line carried by a runabout to proper distance and direction from mooring center.
2.	Position marker buoys at these locations.
3.	Assemble mooring legs (Appendix C) and attach a marker buoy to each anchor crown.
4.	Lower anchors using anchor windlass or gypsy winch, and place the most windward anchor first.
5.	Set drag-type anchors by pulling toward mooring center (chain fully deployed) until firm resistance (~ 2,000 lb) is met. a. Anchor setting distance may vary from as little as 10 ft to more than 50 ft, depending on anchor type, seafloor characteristics, and other factors. b. Repeated failure of an anchor to set should be investigated. It could indicate an irregular bottom, insufficient chain scope, improper initial anchor orientation, or improper fluke angle.
6.	Attach mooring buoy (if desired) or nylon portion of mooring leg.
7.	Install remaining legs, working from the windward to the leeward anchors.
8.	Proceed to position vessel at mooring center and apply tension to mooring legs as required.

(c) Mooring Geometry, Table 9. The mooring is sketched in Figure 22.

distance to anchor from mooring center = RCABL + pennant length + anchor set distance + (vessel length ÷ 2)

= 541 + 150 + 10 + (75/2) = 740 ft

A longer or shorter pennant might be chosen, depending on sea conditions. The mooring would be oriented into the predominant seas.

(d) Excursion. Excursion may be picked directly off appropriate figures; assume a pre-tension of 1,000 lb is achieved.

wind + current - 5 ft (Figures 15,16)
waves (sea state 4, H 1/3 = 7.0 ft) - 5 to 14 ft (Table 3)
total excursion - 10 to 19 ft.

(e) Bill of Materials, Table 12. All four containers are shipped to the site and required materials loaded on the vessel at dockside.

Example 2. This example illustrates the design of a clump anchor system for use in sheltered water with limited sea room.

1. Objective: Same as Example 1.
2. Given: Same as Example 1 except outfall is in a sheltered area with sea room limited to a radius of 600 ft around the diffuser.
3. Find: Same as Example 1.
4. Solution: The mooring specified in Example 1, with a very short pennant might be used.

Another solution would be to use a synthetic line and a clump anchor combined with a drag embedment anchor. This solution will be pursued.

(a) Configuration, Tables 5 and 6. Four-point mooring; θ = 45 deg is selected.

(b) Leg Composition, Tables 7 and 8. A leg composed of a burial anchor, 80-ft chain length, clump, and nylon scope is selected. The clump system will permit reduced scope. The increased mooring stiffness is not critical in sheltered water. Since 80-ft chain lengths are supplied with the system they will be used.

(c) Mooring Geometry, Table 10. Information in Table 10 and maximum available sea room (600 ft) are used to find an acceptable clump size and nylon length.

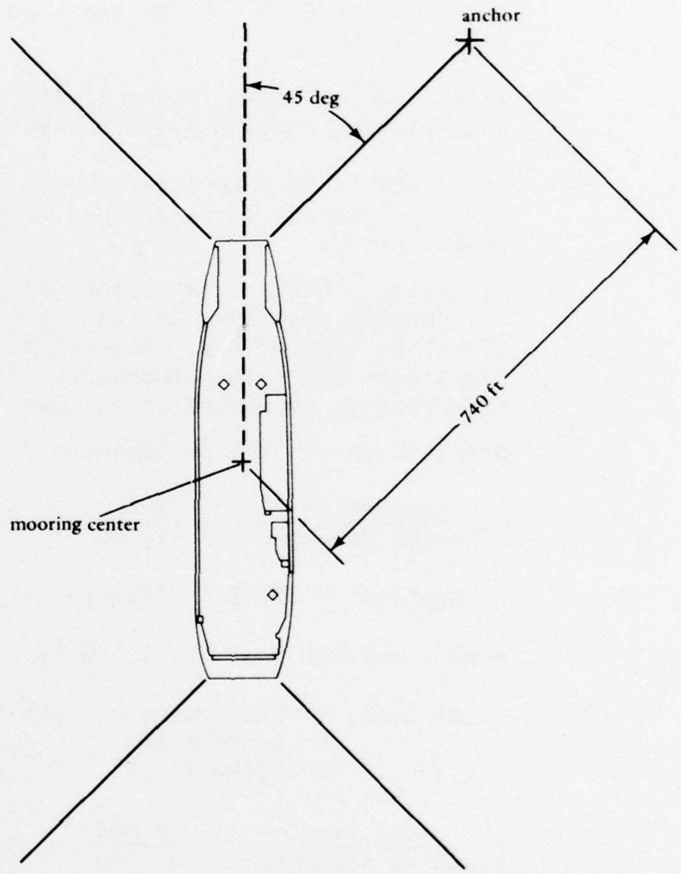


Figure 22. Mooring geometry, Example 1.

Distance to anchor, maximum = 600 ft
= nylon length x cos β + chain length + vessel length/2
= nylon length x cos β + 80 ft + (75/2) ft

$$(\text{Nylon length x cos } \beta)_{\text{maximum}} = 600 - 80 - (75/2) = 482 \text{ ft}_{(\text{maximum})}$$

Enter Table 10 at depth = 100 ft; using trial and error search from left to right to find acceptable nylon length.

With a 200 lb clump, nylon length = 475 ft
nylon length x cos β = 475 x 0.98 = 466 ft

Since 466 ft is less than 482 ft, the selected 475 ft scope and 200 lb (submerged weight) clump are acceptable.

(d) Excursion. Maximum excursion may be roughly estimated by assuming that load on the vessel acts directly along one mooring leg. Stretch of that leg may be found from the nylon elongation curve in Appendix B. Extension is estimated as follows:

pre-tension = 500 lb (assumed)

$$\frac{\text{pretension}}{\text{breaking strength}} = \frac{500}{45{,}000} = 0.011 = 1.1\%$$

elongation = 0.4% (Figure B-1)

wind + current load = 1,500 lb (Table 4)

total load = wind current + pre-tension
= 1,500 + 500
= 2,000 lb

$$\frac{\text{total load}}{\text{breaking strength}} = \frac{2{,}000}{45{,}000} = 0.044 = 4.4\%$$

elongation = 1.5% at total load (Figure B-1)

net elongation = 1.5% - 0.4% = 1.1%

nylon extension = original length x elongation
= 475 ft x 0.011 = 5 ft

excursion = extension x cos β = 5 x 0.98 = 4.9

Therefore, vessel excursion due to maximum wind and current is roughly 5 ft.

Excursion calculated in this way is very rough. In situations where a close approximation is required the problem may be solved by iteration techniques on a digital computer. Graphical techniques are also available (Ref 5).

(e) Bill of Materials. Tables 12 and 10 specify required material

Example 3. This example illustrates procedures for placing a mooring for work along an underwater track (e.g., pipeline, cable).

1. Objective: Lay split pipe sections
2. Given: Track length = 500 ft. The vessel will be oriented into predominant seas. Other factors remain as given in Example 1.
3. Find: (a) Configuration
   (b) Leg composition
   (c) Mooring geometry
   (d) Probable excursion
   (e) Materials required
4. Solution:

(a) Configuration, Tables 5 and 6. Select a four-point mooring.

(b) Leg Composition, Tables 7 and 8. The chain-buoy-pennant and burial anchor composition should be used. It permits easy entry and departure from the mooring and provides good rigidity for working long tracks.

(c) Mooring Geometry. Track length is 500 ft. Mooring angles at the start of the track are 30 deg (bow) and 60 deg (stern). Figure 20 indicates that 1,000 ft of pennant is more than enough for a 500-ft track. The mooring is plotted to scale to find distance to anchors and required pennant length (Figure 23). The first anchor is located by laying off the bow line angle at the start (30 deg) and end (60 deg) of the track. The anchor is located at the intersection of these lines. Total distance to the anchor is scaled off the plot. Pennant length is found by subtraction, using the appropriate RCABL value from Table 9.

$$\text{pennant length} = \text{distance to anchor} - \text{RCABL} = 860 - 540 = 320 \text{ ft}$$

Other anchors may be located similarly by plotting line angles at the start and end of the track; or, they may be located by symmetry about the midpoint of the track.

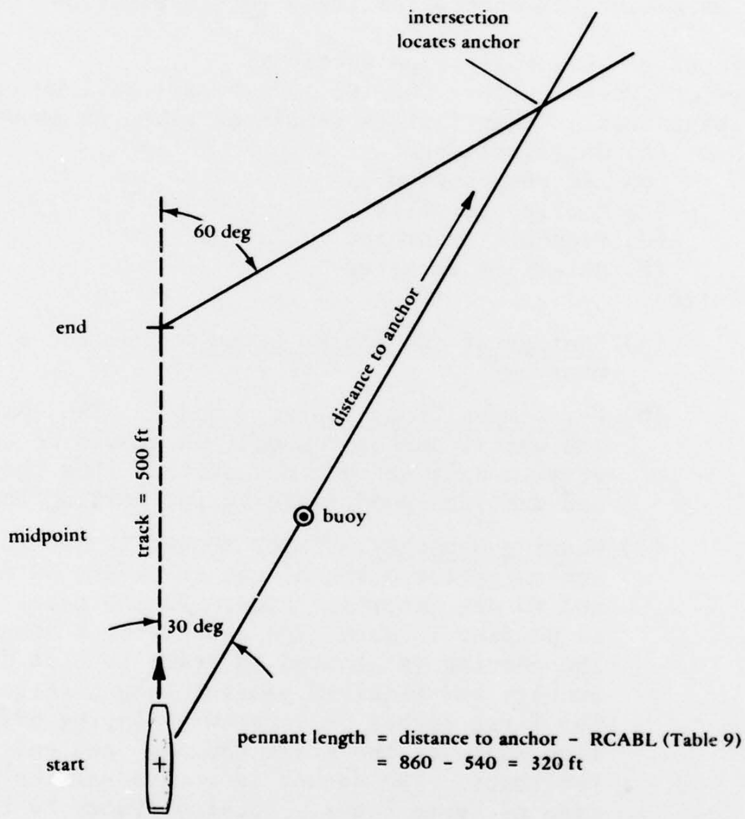


Figure 23. Finding mooring geometry for a 500-ft track, Example 3.

(d) Excursion. Excursion may be roughly approximated by assuming that maximum excursion occurs at the midpoint of the track in a direction perpendicular to the track. At this point the vessel is in a four-point mooring with all leg angles equal to 45 deg. Pretension will be set as high as possible to minimize excursion due to wind and current. Relatively long pennants and deep water should limit wave-induced motions. From Figure 15 with a pre-tension of 2,000 lb and a 100-ft pennant, maximum excursion is 3 ft. Additional excursion occurs because of the stretch of the longer pennant actually in use. The extra extension of a single pennant in this mooring configuration is identical to the additional vessel excursion perpendicular to the track. This makes figuring displacement for a broadside load simple. Total load (1,500 lb, Table 4) is divided by 2 and applied to the appropriate pennant. The extension of the pennant is added to the excursion from Figure 15 to get total beam-wise excursion.

$$\frac{\text{pre-tension}}{\text{breaking strength}} = \frac{2{,}000}{45{,}000} = 0.044 = 4.4\%$$

elongation = 1.8% (Figure B-1)

$$\frac{\text{total load}}{\text{breaking strength}} = \frac{2{,}000 + \frac{1{,}500}{2}}{45{,}000} = 0.061 = 6.1\%$$

elongation = 2.5%

net stretch = (0.025 - 0.018) x (actual pennant length - 100 ft)

Actual pennant length is found by measuring distance to anchor at track midpoint and subtracting:

$$\text{pennant length} = \text{distance to anchor} - \text{RCABL}$$

$$= 660 - 540 = 120 \text{ ft}$$

net stretch = 0.007 x 20 = 0.1 ft (which is negligible in this case)

$$\text{total excursion} = 3.0 + 0.1 = 3.1 \text{ ft}$$

(e) Bill of Materials. Basic material requirements are found in Table 12. Nylon required per leg was found in part (c) of the Solution to be 320 ft minimum.

ACKNOWLEDGMENTS

Suggestions and criticisms from LCDRs Stamm (UCT-2) and Weiler (UCT-1), Master Chief Petty Officer Worjohnen, and Chief Petty Officer Standfill (UCT-1) were invaluable in choosing mooring system components and in preparing this guide. The following personnel from CEL were of special help. Messrs. R. Brackett and R. Erich aided in the selection, procurement, and assembly of hydraulic controls and layout; Mr. D. Davis provided estimates of small craft motions due to waves; Mr. M. Stern designed the windlass and winch support assemblies; Messrs. R. Taylor and P. Babineau lent their practical knowledge in choosing durable, useful components and in reviewing this guide.

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Appendix A

WINCH AND WINDLASS LOCATION PLANS AND BASE ASSEMBLIES

The windlass (winch) base and adaptor assembly provides a mounting platform on vessels of opportunity (see Figures A-1 through A-3). The windlass base also raises the windlass so that chain may be recovered above deck. If drilling through vessel deck plates is acceptable and a chain locker is available, the windlass base is not required. In all cases, choose a deck area with as much substructure support as possible.

Two procedures for installing the winch and windlass are suggested:

1. Bolt windlass (winch) to base. Weld adaptor to deck. Bolt windlass (winch) base assembly to adaptor. See procedure below for welding windlass adaptors to deck.
2. If this is not possible, the following procedure may be used to minimize lifting requirements:
   a. Weld appropriate aluminum or steel adaptor to deck. For the windlass adaptors the following procedure is recommended:
      (1) Using the plywood template provided, tack-weld the adaptor to the deck.
      (2) Remove template and complete welding adaptor to deck.
   b. Bolt base assembly to adaptor.
   c. Bolt windlass or winch to base.

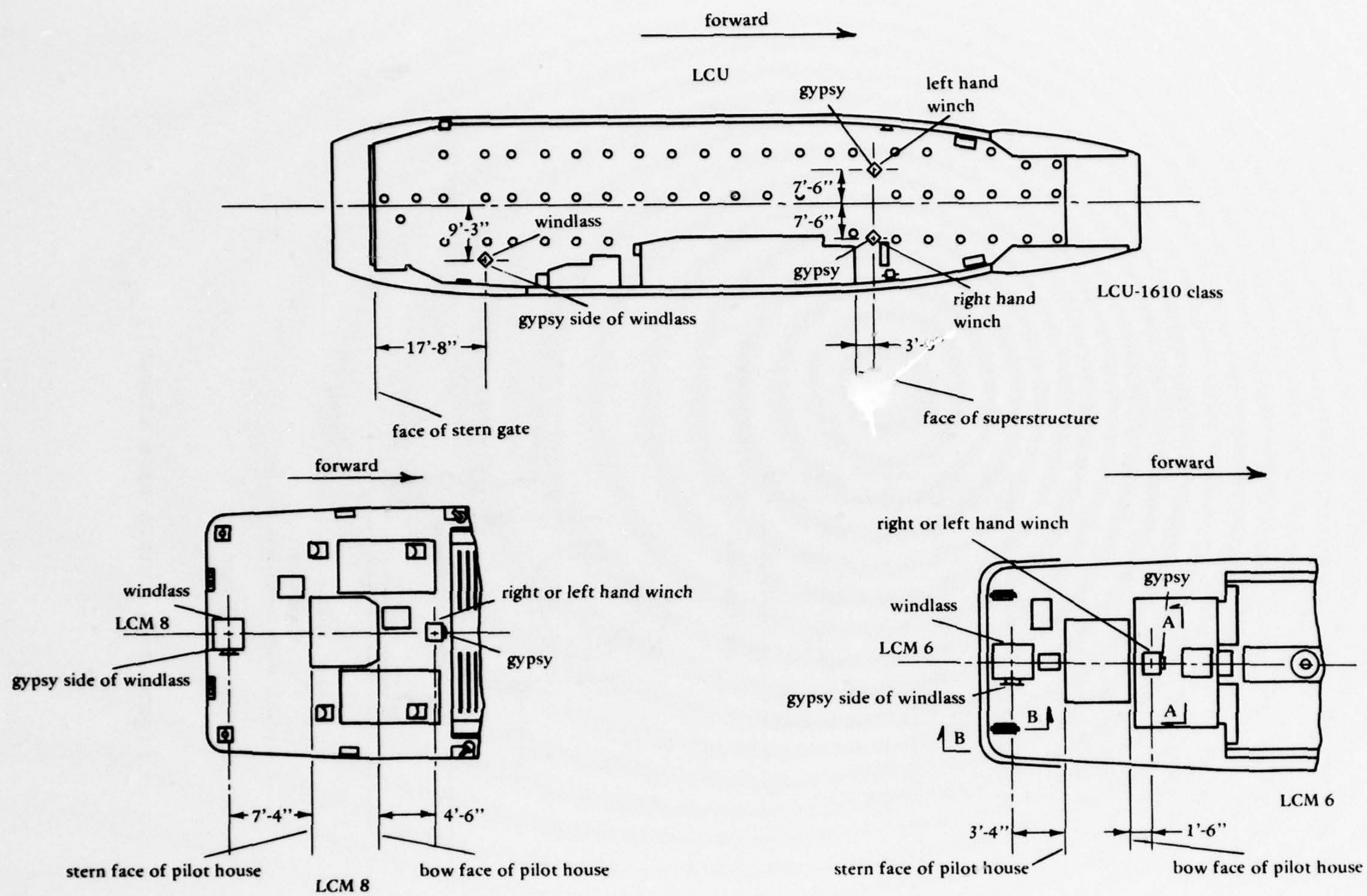
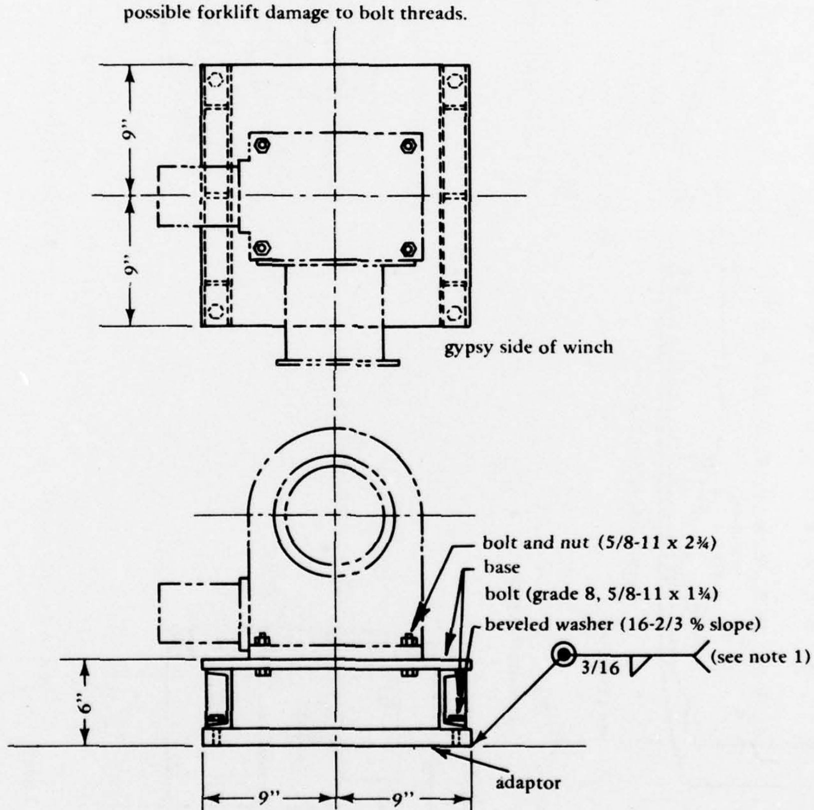


Figure A-1. Suggested winch and windlass location for LCU-1610, LCM 8 and LCM 6.

NOTES:

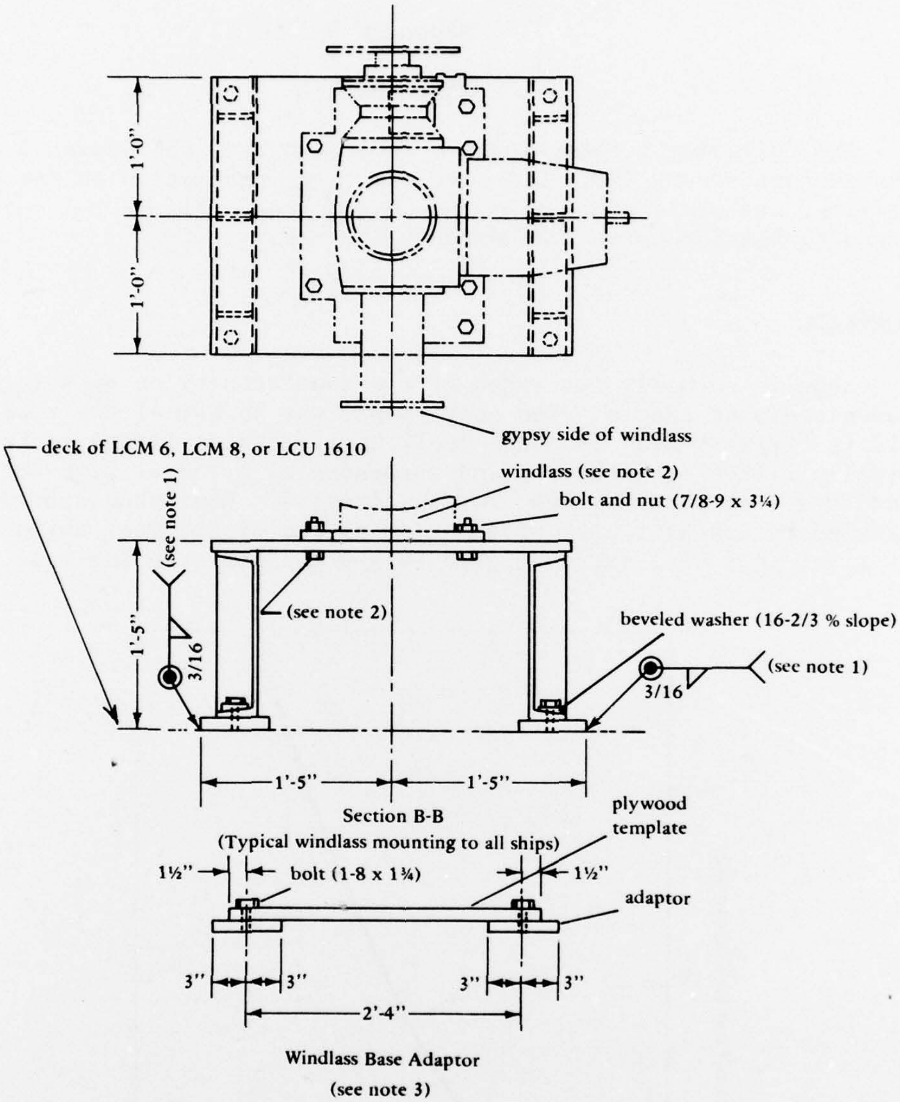
1. Adaptor shall be furnished in aluminum or steel depending on whether the ships deck plate is aluminum or steel. For steel welds use welding rod E70XX. For aluminum welds use filler alloy 5356.
2. Install bolt heads as shown in sections A-A and B-B to prevent possible forklift damage to bolt threads.



Section A-A
(Typical winch mounting to all ships)

deck of LCM 6, LCM 8, or LCU 1610

Figure A-2. Winch base assembly.



NOTES:

1. Adaptor shall be furnished in aluminum or steel depending on whether the ship's deck plate is aluminum or steel. For steel welds use welding rod E70XX; for aluminum welds use filler alloy 5356.
2. Install bolt heads as shown in Sections A-A and B-B in order to prevent possible forklift damage to bolt threads.
3. Plywood is used as a template for welding adaptor to deck of ship. After tack welding to deck of ship, remove plywood template, complete the welding, and bolt base to adaptor.

Figure A-3. Windlass base assembly.

Appendix B

NYLON ROPE

The following information was excerpted from the Samson Ocean Systems Rope Manual (Ref. 13). It provides information on the care, handling, and performance of Samson nylon rope. Figure B-1 shows the stress-elongation curve for Samson nylon rope.

UNREELING

Rope is normally furnished by the manufacturer on nonreturnable wooden reels or spools. The only proper way to unreel the rope is to pull it straight away from the reel, as it rotates (large reels are normally lifted or jacked-up and suspended by a rod or pipe through the drum core - so that the reel rotates freely). Rope should never be unreeled by taking it off of the head or end of the reel while it is on its side; this will surely create twists and kinks in the rope.

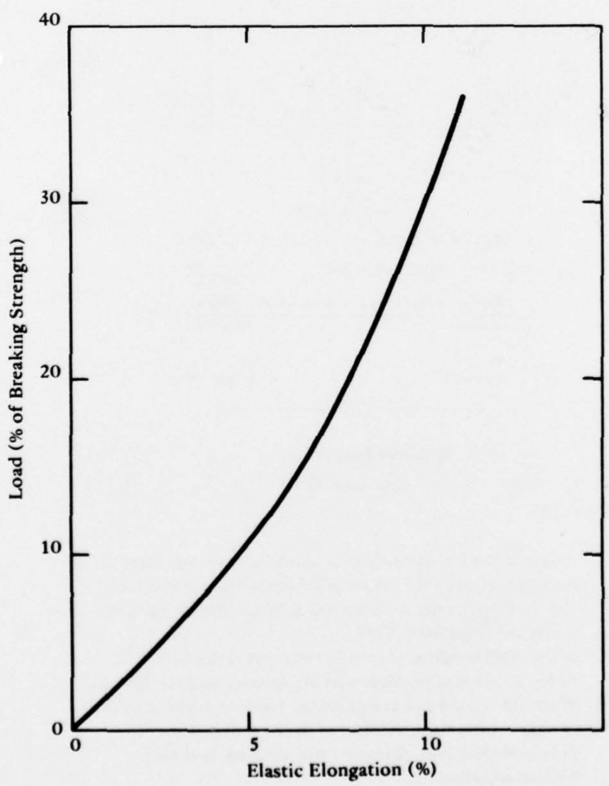


Figure B-1. Stress-elongation curve for new, dry Samson 2-in-1 nylon rope (from Ref 6).

SHEAVE DIAMETERS AND SIZES

For braided rope, sheave diameter should be at least 8 times larger than rope diameter. The width or diameter of the sheave groove should be at least 10% greater than the diameter of the rope. Groove shape should be circular; V-shaped grooves pinch and damage the rope through excessive friction and crushing of the fibers. For smooth rotation, sheave surfaces should be kept smooth and free of burrs and gouges, and bearings should be in good condition.

In regard to minimum turns when working off a drum, the line should not be extended to a point that would leave fewer than four turns on the drum.

BENDING RADII

Any sharp bend in a rope under load decreases its strength substantially and may cause premature damage or failure. Many rope users are surprised to learn that a simple overhand knot (a series of sharp bends) reduces rope strength by almost 50%.

On sizing the radius of bitts, fairleads, and chocks for best performance, the following guidelines are offered:

> Where a rope bends more than 10 deg around bitts or chocks or, for that matter, is bending across any surface, the diameter of that surface should not be less than three times the diameter of the rope. Another way of saying it is: the diameter of the surface should be at least three times the rope diameter. A 4/1 ratio (or larger) would be better because wear life of the rope increases substantially as the diameter of the surface over which it is worked increases.

ABRASION, CHAFING/FRICTION

After some use and exposure to bearing surfaces, the outer fibers of ropes have abraded and broken and form a fuzzy surface appearance and texture. This actually results in a protective cushion and shield that retards additional abrasion and damage to the subsurface fibers. In manila and sisal ropes, these broken fibers act as splinters and make handling of these ropes quite unpleasant. In synthetic ropes, especially of the multifilament type, the surface becomes soft to the touch, while providing better gripping characteristics. The strength loss due to these broken surface fibers is negligible (unless, of course, the damage extends deep into the rope).

All ropes should be protected against sharp and abrasive surfaces. Chocks and bitts that have been scored and gouged by the previous use of wire rope become cutting edges for synthetic or manila ropes. Weld-beads

on repaired capstans, fairleads, or other pieces of equipment are equally damaging unless dressed down smoothly. Sheaves in hoisting rigs should be examined carefully for surface burrs and sharp edges. Generally speaking, if wire rope has been used previously over a sheave, then the sheave should be replaced if synthetic rope is to be used.

Thimbles (new or old) should be dressed down smoothly on the rope-contact surfaces before being spliced into a rope eye. Bent and distorted thimbles should be replaced because damage may expose rope to a sharp edge. A badly stress-distorted thimble will have a reduced bending radius and, thus, reduce rope strength.

Dragging rope over concrete docks and floors (which generally have a highly abrasive surface) should be avoided.

Pulling rope over the ground may cause it to pick up grit particles, which, once imbedded, may cause internal abrasion of the fibers.

Ropes, regardless of fiber content, should always be kept away from rusty surfaces of iron or steel. In addition to having an abrasive action on the fibers, rust also has a chemically degrading effect upon most fibers, including nylon and polyester.

Friction of synthetic ropes under high tension generates heat (often high enough to melt or fuse the outer fibers). This fused skin will sometimes stick to the surfaces of bitts and capstans and then slip, causing a series of jerks as the rope is used. This condition is more common with polypropylene and polyethylene ropes, which have lower melting points. Nylon and polyester ropes are recommended where this condition is apt to occur, but care must be taken with all synthetic ropes when "easing out" lines under heavy load. To be avoided whenever possible is the deliberate practice of relaxing wraps on a capstan or gypsy head in order to hold-your-own while the capstan continues to turn. This will fuse lines badly, resulting in strength loss.

A light surface glaze of fused fibers may develop in areas of a line exposed to normal wear in hard work over bitts, chocks, capstans, etc.; this is no cause for concern, as strength loss is negligible.

CLEANING OF SYNTHETIC ROPES

Most synthetic ropes may be washed with a mild detergent and warm water without any harmful effects. However, strong grease detergents, cleaning agents, bleaches, and chlorinated hydrocarbons should be avoided, as should steam cleaning. Some strong grease detergents may actually remove the natural lubricant of the rope fibers, causing undue internal wear from fiber friction. This would naturally shorten rope life.

COILING, FAKING, AND ROPE STOWAGE

Braided ropes have no built-in twist and are resistant to kinking. Even if kinks do develop, they cannot develop further into hockles.

The best method for making up braided rope for deck stowage is in figure-8 fashion - either faked flat on the deck or vertically around bulkhead cleats. It should not be hand-coiled in either direction, as

this merely puts turns into the line, which may develop into kinks when paying-out. Remember: there is no turn or twist in the line to begin with, so, do not produce it by coiling.

Surprisingly, there is an equally effective, and much easier, method for stowing double-braided ropes (especially where they are being put down into deep holds or line lockers): dump the line at random. This suggestion horrifies many "old salts," but it works. This idea also offends the sense of order and neatness of some skippers and sailing purists, but those who have used this method find it a real labor saver and perfectly harmless to the rope. Actually, size-for-size, more double-braided rope can be stored in the same cubic space, in this fashion, than can three-strand ropes that are coiled or faked. In paying out lines stowed in random-dumped fashion, it pays out very smoothly, even at fairly high speeds without any kinking or tangling of bights.

Improper stowage can cause permanent damage, and seriously affect the service life of many ropes.

Synthetic ropes are impervious to damage from rot; and, though mildew may form on them, it has no detrimental effect. Water, lack of ventilation, and normal stowage temperatures have no appreciable effect.

Storing synthetic ropes in direct sunlight over prolonged periods should be avoided where possible - especially with small diameter ropes - because of gradual strength degradation caused by ultraviolet rays. This is not as important, however, in ropes of larger sizes, where strength loss is negligible (Ref 13).

Appendix C

RIGGING DETAILS

Suggested rigging for the chain-buoy-pennant, all-synthetic and clump-synthetic leg compositions are shown in Figure C-1.

The fairleading mooring lines are passed to the windlass (winch) directly or through appropriately placed snatch blocks. The blocks are to be attached to a reinforced deck or bulkhead area (e.g., cleat, lifting eye).

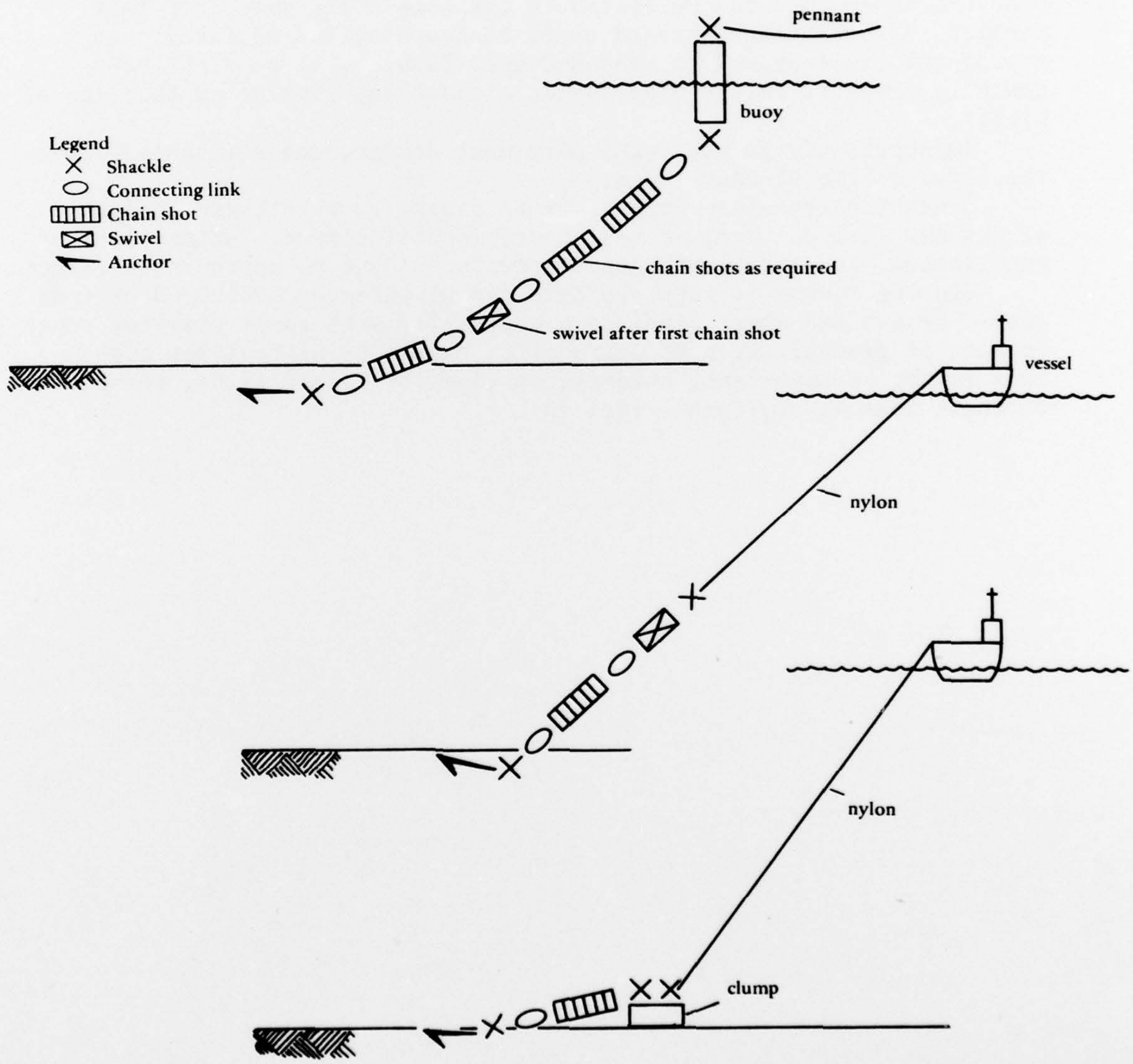


Figure C-1. Rigging details.

Appendix D

HYDRAULIC SYSTEM

A typical series flow hydraulic schematic is shown in Figure D-1. In the arrangement shown, both winches and the windlass operate simultaneously or individually. Hydraulic hose is provided in 30-ft lengths to permit a variety of flow schemes to meet particular requirements. Supply line is 3/4 in. in diameter and return lines are 1/2 in. in diameter.

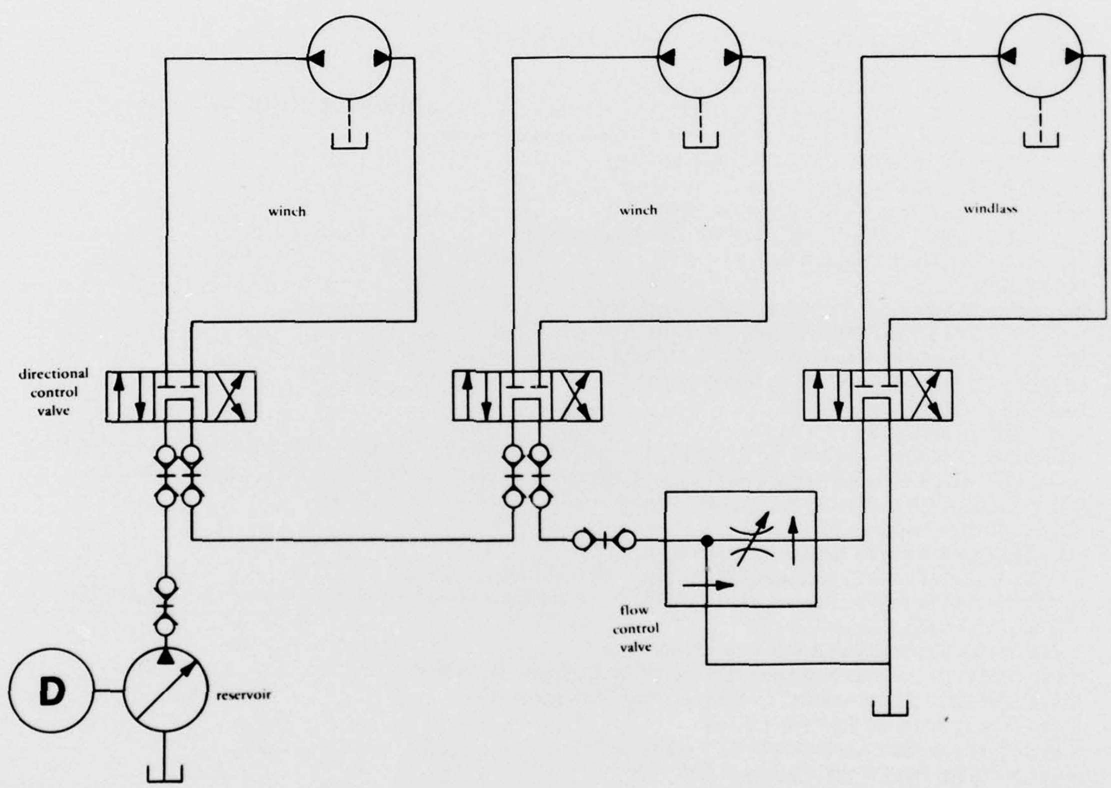


Figure D-1. Hydraulic schematic (typical arrangement).